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Development of Integrated Programs for Aerospace-Vehicle Design (IPAD) - Product Program Management Systems

J. M. Isenberg and J. W. Southall

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Development of Integrated Programs for Aerospace-Vehicle Design (IPAD) - Product Program Management Systems

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FOREWORD

This document was developed as part of the Integrated Programs for Aerospace-Vehicle Design (IPAD) program documentation in accordance wth contract NAS1-14700. Other closely related IPAD documents are:

NASA CR 2981	Reference Design Process (D6-IPAD-70010-D)
NASA CR 2982	Product Manufacture Interactions With the Design Process (D6-IPAD-70011-D)
NASA CR 2984	Integrated Information Processing Requirements (D6-IPAD-70012-D)
NASA CR 2985	IPAD User Requirements (D6-IPAD-70013-D)

The NASA Langley Research Center Document Coordinator for this document was David D. Loendorf.

Measurements included in this document were not generated on the IPAD program; therefore, they are shown here in U. S. customary units. A conversion table (U. S. to S. I.) is included in appendix B.

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CONTENTS

FIGURES

1.0 SUMMARY

Engineering projects such as aircraft, spacecraft, etc., are organized as product programs. The program serves to integrate functional departments such as marketing, finance, engineering, and manufacturing. This document describes the management systems used to integrate or interface functional elements of the program.

The basis for technical direction consists of the work breakdown structure (WBS) and design-to-cost functions. The WBS is a structured index of the end products to be produced by the program. It promotes understanding of all tasks and provides a mechanism for cost collection. It subdivides the program into manageable work areas and includes a numbering system to relate functional aspects to control media. The design-to-cost functions acknowledge program controls emphasizing cost as a dominant factor in system and hardware design. A design-to-cost board has responsibility for design-to-cost implementation. Work package teams are organized to accomplish the elements identified in the WBS. Trade studies are evaluated for cost effects on baseline target costs. Monitoring and control features based on the WBS provide periodic audit type comparisons of target costs to the current predicted costs for each WBS element and are "rolled up" to identify total program costs. Life-cycle costs and post-development objectives are considered prior to design release.

A baseline master schedule is used with control based on a hierarchy of tiered schedules aligned to the WBS, including both "work-oriented" and "milestone-oriented" schedules. Reporting provides a centralized source of schedule status and milestones.

The WBS is used to plan, control, and report budgets, costs, schedules, and performance.

Product configuration management consists of configuration definition and identification (usually of a baseline) and the change controls required to effectively iterate the baseline to the final product(s).

Policy establishes responsibilities for business, engineering, and manufacturing data processing systems. Data administration is recommended.

Engineering schedule and budget tracking is based on a central source of schedule and job status.

Management information is a combination of automated and manual displays presented in a visibility room.

2.0 INTRODUCTION

This document gives a brief description of management systems used to direct and control a product-oriented program. Figure 1 illustrates the relationship of the document to other task 1 documents. Figure 2 shows relationships of the various management tools. The primary elements of technical direction consist of the work breakdown structure (WBS) and the design-to-cost procedures adopted for the product program. The development of a WBS and the implementation of Design-to-Cost are discussed in section 4.0. Schedule management, including controls and reporting, is discussed in section 5.0. Resource management, including controls and reporting, is discussed in section 6.0. Product configuration management during all phases of the product program is discussed in section 7.0. Data management is discussed in section 8.0 in terms of data processing policy and data administration. Accounting systems to track engineering schedule and budget performance are discussed in section 9.0. Visibility and display of management information are discussed in section 10.0.

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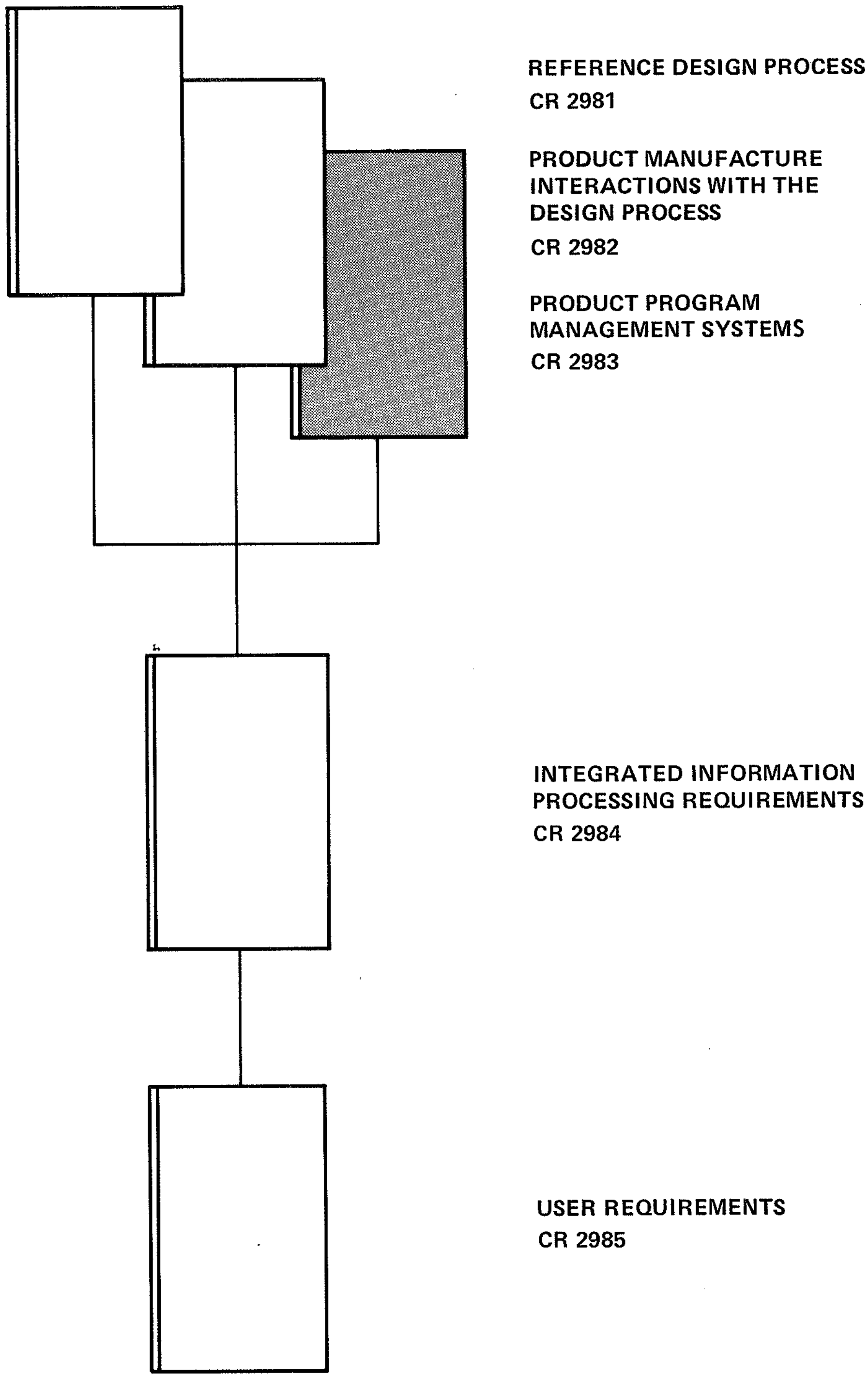


Figure 1.—Relationship of Task 1 Document

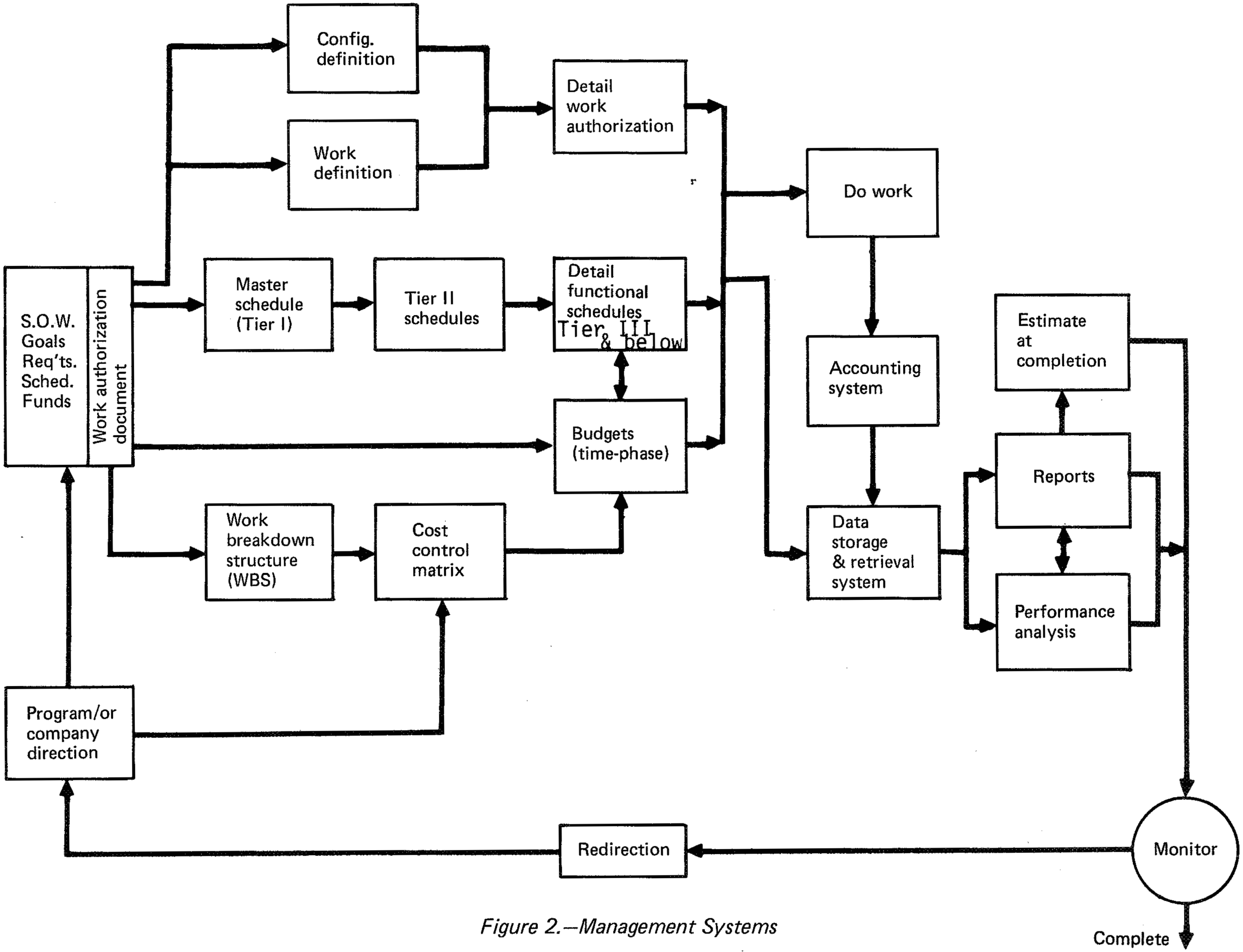


Figure 2.—Management Systems

3.0 ABBREVIATIONS

ADJ	Adjusted
BUD	Budgeted
CAL	Calendar (%)
CO	Change Order
COMPL	Completion (current scheduled)
COMTD	Completed (original commitment)
CUM EXP	Cumulative expenditures
DDM	Design decision memo
DTCR	Design-to-cost report
EAC	Estimate at completion
ECP	Engineering change proposal
EXC	Exception signal
EXP	Expended
FCST REM	Forecast remaining
IPAD	Integrated programs for aerospace-vehicle design
JS	Job status
M	Manual
PB	Past budget (cumulative manmonths)
PD	Preliminary design
PE	Past expenditures (cumulative manmonths)
PS	Past manning schedule (cumulative manmonths)
PIN	Program item number
QC	Quality control
SCH	Schedule
SOW	Statement of work

SRC	Special requirements code
SSD	Status source document
TE	Trailing edge
TSR	Trade study request
WBS	Work breakdown structure

4.0 TECHNICAL DIRECTION

This section delineates the prime management tools used to identify and direct all program work items.

4.1. WORK BREAKDOWN STRUCTURE (WBS)

A program work breakdown structure is a product-oriented family tree composed of elements that result from program efforts during the development and production of a product. A WBS is a structured index of the product(s) to be developed or produced and relates the elements of work to be accomplished to each other and to the end product(s) and provides a common denominator against which all planning, scheduling, costing, and accomplishments are related.

It is developed downward by proceeding from the definition of the program/project objective through successive levels to the lowest level of detail required for effective program planning, control, and support.

4.1.1 WBS PURPOSE

The WBS is used as the forcing function to establish standardized nomenclature, definition, and orderly arrangement of all major elements (hardware, software, services, data, etc.) and in planning for allocations, estimates, actions, and work execution. The reporting of progress, performance, and evaluations shall be based on the WBS.

The WBS serves as a prime management tool, starting in Engineering and encompassing all program disciplines: engineering, operations, business management, customer relations, etc. WBS is used to plan, control, and report:

Budgets--Identified on program control matrix by organization, WBS element, and significant work order

Costs--Charged, collected, and reported through a charge number structured to the significant WBS code

Schedules--By WBS element and code number

Performance--Tracked and reported by organization, WBS element, and WBS code

4.1.2 WBS DEVELOPMENT LOGIC

Unlike the product design levels (see D6-IPAD-70010-D), the complete WBS does not emerge at the beginning of a program. Its development evolves through the total product definition phase and normally is not totally defined until the detail design phase (fig. 3, WBS development phasing).

Levels are used to define the WBS and are described as follows:

Level 1: Total product program

Level 2: A logical grouping of functional categories of the program, i.e., major product hardware elements (structure, functional systems, propulsion, and power); development; management; services; and support

Level 3: Major subdivisions of the level 2 elements, i.e., structure (wing, body, etc.) and test (laboratory, flight test, etc.)

Levels 4 and on are logical subdivisions of the upper-level elements. The lower levels of the WBS will vary from program to program depending on the company organization, product design complexity, configuration management procedures, etc.

4.1.3 WBS ELEMENT IDENTIFICATION

Each WBS entry is assigned a unique program item number (PIN). The PIN's are developed with a significant numbering system to provide identification of the various program systems. (See fig. 6.)

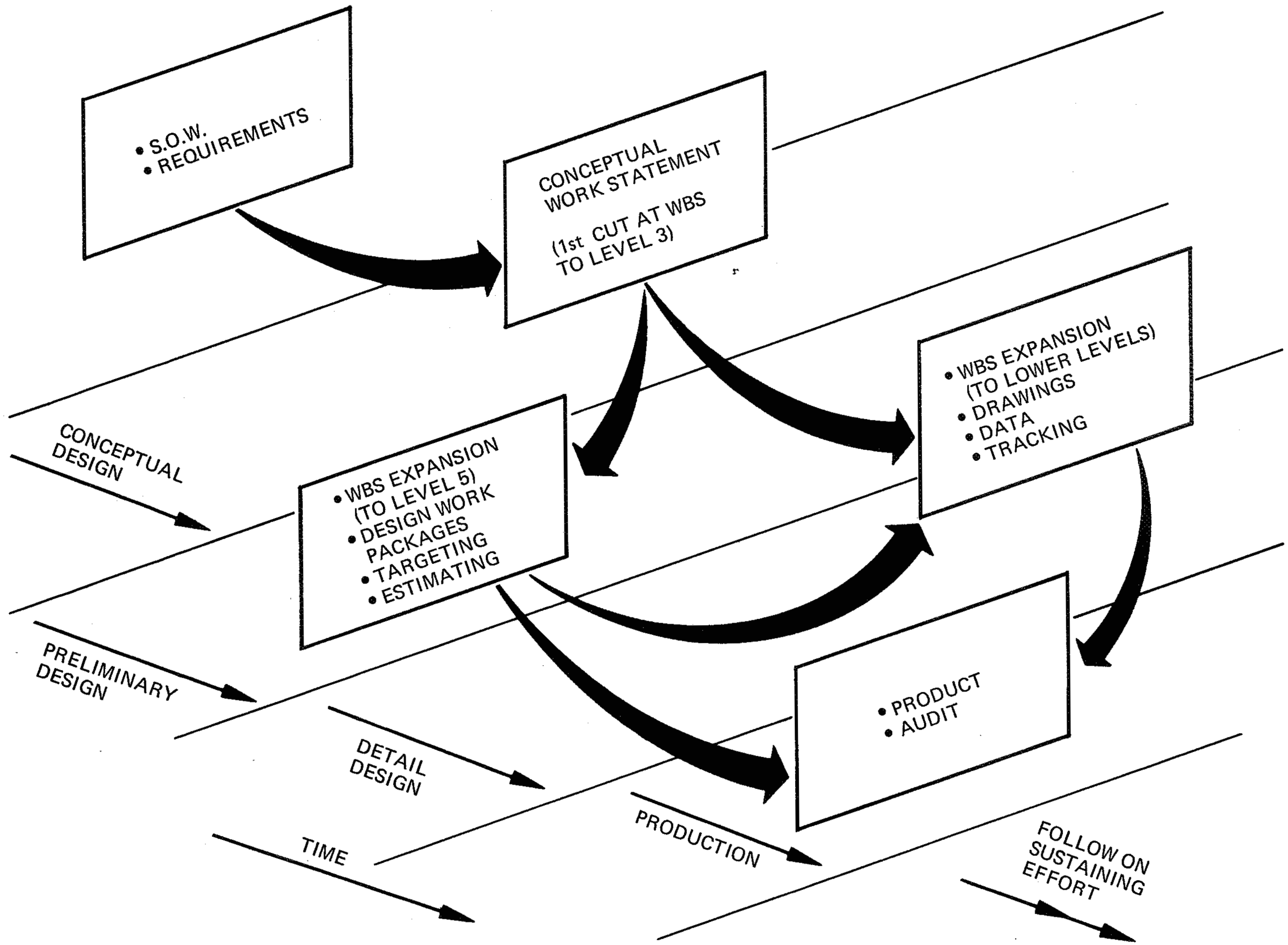


Figure 3.—WBS Development Phasing

The level 1 program element is assigned a three digit program identifier. Level 2 elements are assigned individual digits in numerical sequence, i.e.,

0 = Product integration and assembly

1 = Structure

2 = Systems

3 = Power

4 = Test development and evaluation

5 = Management

The subdivisions of each WBS element at each level are assigned individual digits starting with zero for "product integration and assembly." It should be noted that there should be no more than ten subdivisions for any WBS element at each level. This allows for uniform number sequencing and provides "roll-up" capability (see fig. 4). Figure 5 depicts a WBS "tree" and shows the identification logic.

The program item number (PIN) can be the basis for a single uniform identification. The following are examples:

A charge number should contain:

Type of work--fabrication, minor assembly, engineering design, quality control, etc.

Cost account--Program identifier and WBS levels 2 and 3 PIN

Package identifier--levels 4 and 5 PIN

Type of effort--preliminary design, basic design, engineering change proposal (ECP), test, sustaining, etc.

Performing organization

Responsible organization

Manufacturing analysis sheet--The planning sheet identified by the PIN for the particular WBS element

Purchase order--identified by the cost account and package number

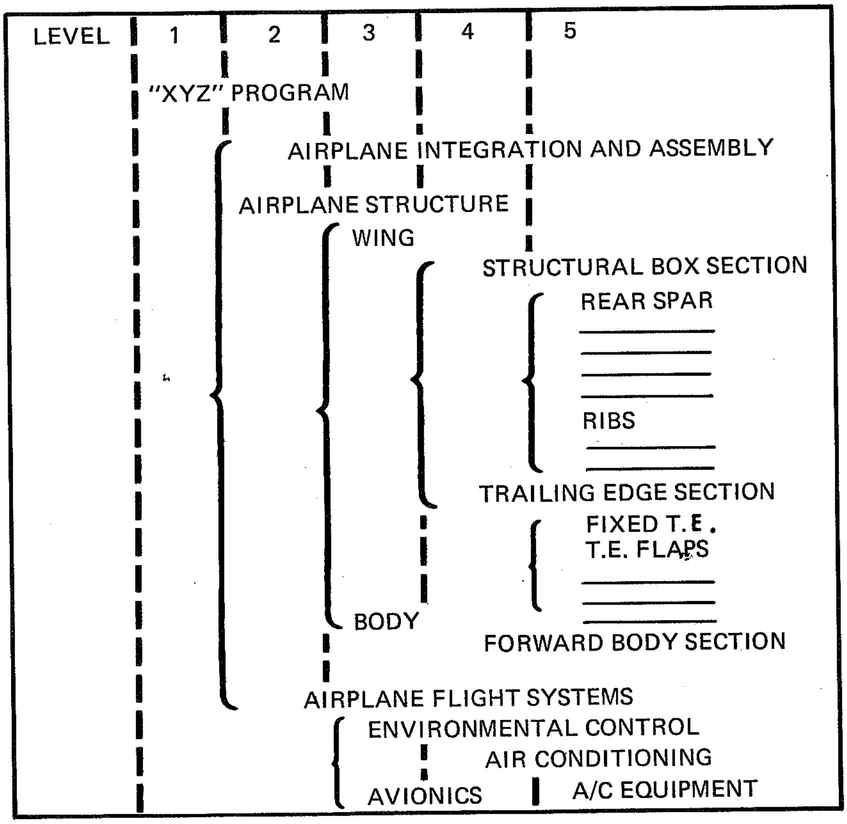


Figure 4.—WBS "Roll-Up" Criteria

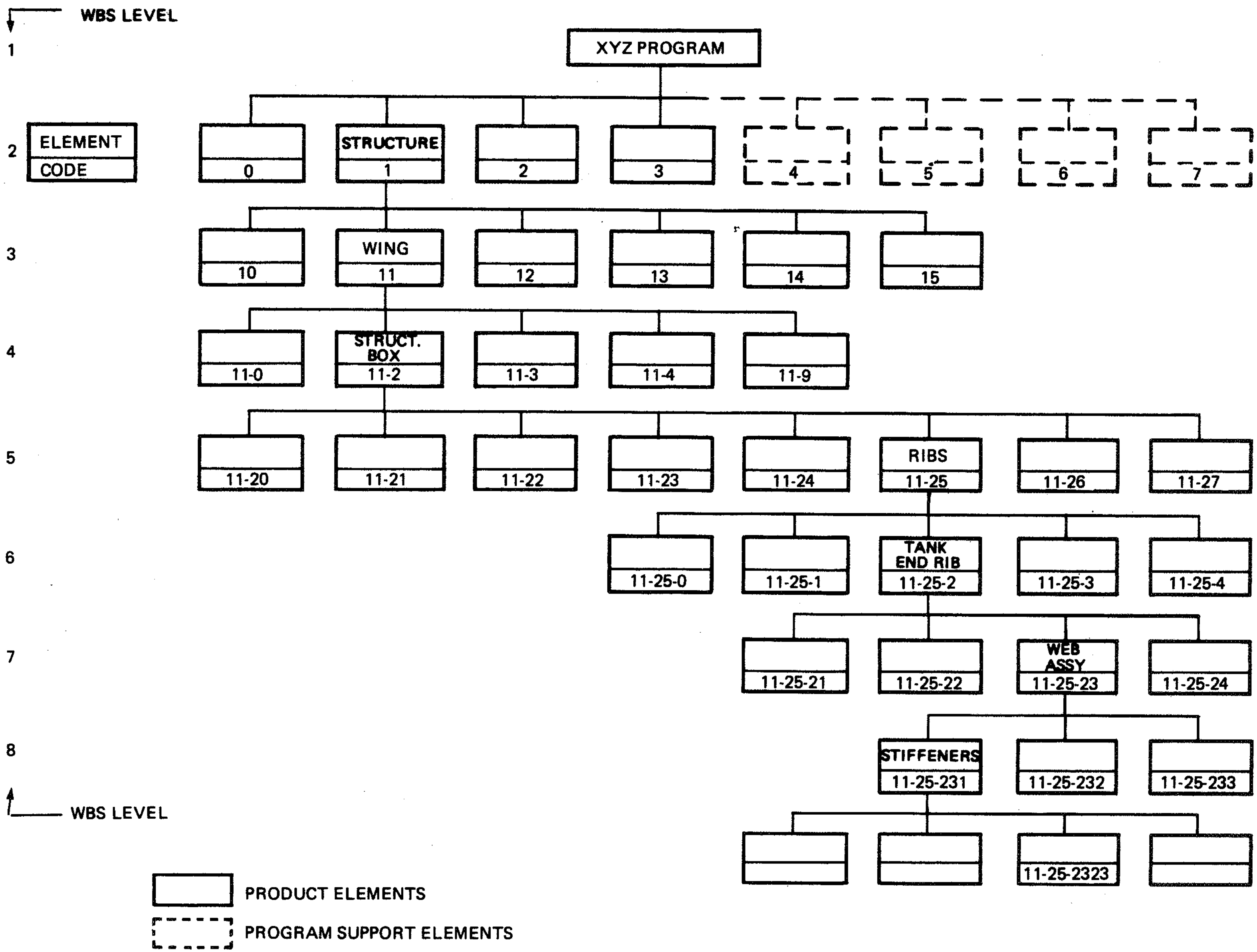


Figure 5.—Example WBS Tree

Detail schedules--identified by PIN of the WBS level being scheduled.

Tool order/tool--identified by drawing number with a tool code prefix. The drawing number should contain the applicable PIN.

4.1.4 WBS SIGNIFICANT NUMBERING APPLICATION

Figure 6 depicts the relationship between various program control media. The WBS program item number (PIN) is the base that should be in all program systems identifiers. Following are examples of identification logic:

PIN description--a description of the hardware contained in the WBS element identified by the PIN

Work package document--identified by the WBS level 4 PIN

Equipment list--the required standards and purchased equipment contained in and identified by the work package PIN

Engineering drawing--should contain:

Program identifier

PIN to at least level 4

Model

Random identifiers for the various parts that make up that drawing

Engineering advance material release--identified by program identifier and PIN

Actual costs--collected by cost account and package identifier through the cost collection system

Performance report--rolled up and identified to any WBS element by its PIN

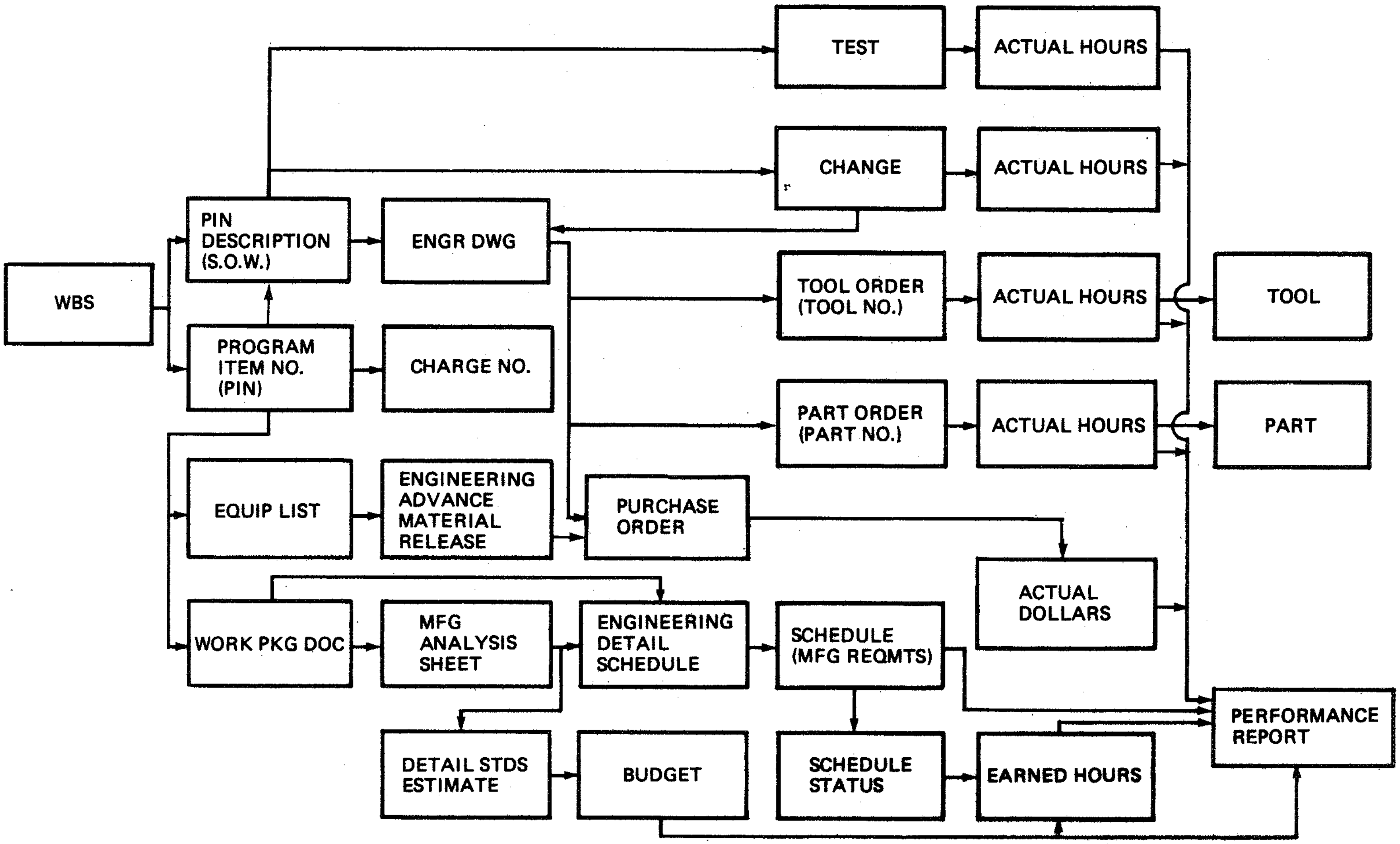


Figure 6.—WBS-Oriented Significant Number Application

4.2 DESIGN-TO-COST

Design-to-cost is the establishment of product cost goals prior to detail design commitment and the utilization of management disciplines to achieve cost goals through all phases of the product life cycle. The design-to-cost effort must provide the manager with data for cost goal assignment. This is accomplished through the implementation of discrete work packages and work package teams comprising engineering, manufacturing, materiel, quality control, finance, and other appropriate organizational personnel. These teams produce designs from known realistic requirements to ensure accurate, predictable costs throughout the product life-cycle. Program controls must emphasize cost as an equal factor when product performance and schedule decisions are made.

4.2.1 DESIGN-TO-COST PLAN

The program design-to-cost plan must apply design-to-cost disciplines in all areas of system and product design. The plan must ensure that cost is given equal consideration with other major design requirements such as performance and schedule. The major elements of the plan are described as follows.

4.2.1.1 Policy

Design-to-cost is the formal acknowledgment of program controls which emphasize cost as a dominant factor in system and hardware design and serves to drive acquisition and life-cycle costs down to their lowest attainable levels. A team approach is used to achieve this intent. All necessary functional support is given to the design effort. "Design," as used herein, includes all of the steps from system and product conception through physical completion and readiness for delivery.

4.2.1.2 Design-to-Cost Board

The program manager has complete responsibility for design-to-cost implementation. He selects a design-to-cost manager to assist him in this responsibility. The design-to-cost manager spends his time working with the functional managers to emphasize the importance of the design-to-cost effort. He has the responsibility for establishing design-to-cost disciplines and chairs a Design-to-Cost Review Board composed of members of engineering, manufacturing, materiel, quality control, and finance (and other functional organizations that he may deem necessary). The Design-to-Cost Board monitors and reviews the design activity and exercises its authority to maintain or drive the cost elements so that they can be achieved at or below the cost goals. The

Board also selects the principal (both acquisition and ownership) cost drivers in the design (historically, 75 percent of cost is associated with 25 percent of weapon system components) and ensures that particular emphasis is placed on these items.

Work package teams are responsible for breaking out and allocating element cost goals from the total cost goal. Program management establishes functional cost goals.

4.2.1.3 Work Package Teams

The design-to-cost manager directs the creation of work package teams. These teams are be designated at least down to the WBS level 4. Key features of the work package team include:

Systems, product assurance, design, manufacturing and quality engineers, and materiel, located in a common area and assigned specific work package responsibility

Use of a documented design standards plan delineating maintainability standards, common tooling philosophies, design tolerances, materials, processes, standard hole, and thread classes

Formal participation of manufacturing engineers and product assurance personnel beginning with systems and design concept and concluding with finite manufacturing and tooling plans <u>prior</u> to a producibility engineering approval signature on the engineering drawing

NOTE: Manufacturing and tooling plans for both development and production will be written. The production plans are used as the basis for the refined estimate of the average production unit cost. The development planning is released to support hardware fabrication.

Formal approval by quality assurance that inspection requirements do not increase costs disproportionately to their intrinsic value but meet internal and contractual needs

The work package teams assist in developing the subdivision of the allocated level 4 WBS targets down to the lowest practical level. The targets are a projection of the average production unit cost. This unit is a specifically identified production line unit determined by the intersection of the straight-line average with the projected learning curve (fig. 7).

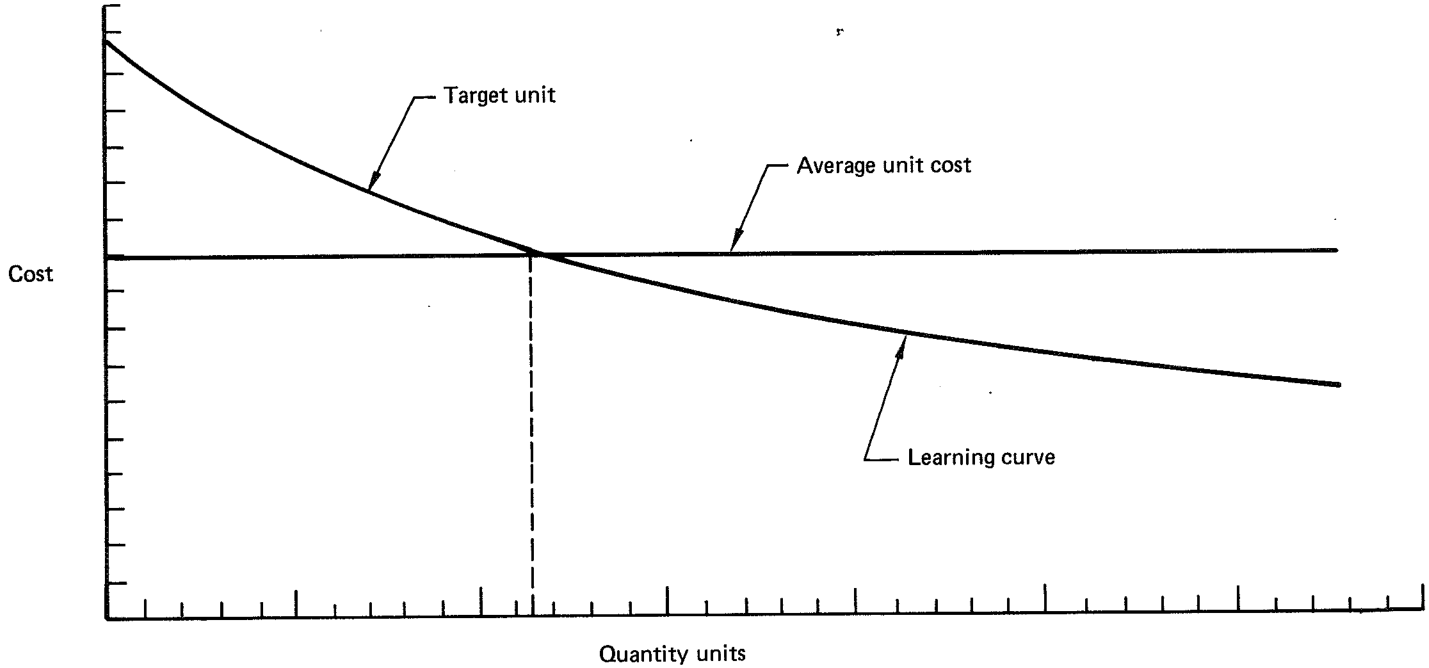


Figure 7.—Cost Target—Unit Selection

The targets or "ceilings" applied to the system components are specified internally by labor standards. These units are more constant than dollar-valued or basic factory labor hours and can be converted by the application of current basic factory labor or dollar factors. Raw material and purchased items have "time-locked" or standard dollar targets that can be converted by an inflation index to current values. The inflation factor should be mutually agreed to by all parties.

The work package teams ensure that system, concept, and initial designs are producible, maintainable, and reparable and that manufacturing and inspection methods are incorporated in consonance with contractual requirements and company standards.

4.2.1.4 Design-to-Cost Application

Cost targets are shown on cost target sheets which are designed so that estimated costs are segregated and trackable (fig. 8). These sheets are compiled for all design items and published in a common document. Estimated costs are applied, as are the deltas from the target to the estimate. The cost target sheets are the data base for compiling the periodic design-to-cost report (DTCR). At the conclusion of the development program, the final cost target document is used to assess and develop the design status impact on the design-to-cost goals.

The estimates and deltas are reviewed and updated by the manufacturing and/or materiel members of the work package teams as the design develops. These deltas are periodically reviewed (usually on a two-week basis) by the Design-to-Cost Review Board. Significant upward trends or drifts in the deltas precipitate action ranging from informal direction to the release of design decision memos (DDM's) that will effectively freeze the design until appropriate corrective measures can be taken.

4.2.1.5 Trade Studies

The cost targets of recurring and nonrecurring standard hours and procurement dollars are the springboard for initiating trade studies on the development program when evaluation confirms that conceptual or preliminary designs cannot be produced at or below the baseline (target) cost.

Trade studies are formally requested via the trade study request (TSR) form (fig. 9) initiated by work package team members or the Design/Cost Review Board.

WBS elements	Target										Estimate no.				Date						Under target	Over target
	Total				Cost per unit—xxx units						Total				Cost per unit—xxx units							
	Engrg basic M/hrs	Dev $	Tool-ing (BSC) M/hrs	P .E. non-rec. $	Fab M/hrs	Assy inst. M/hrs	Mat'l $	O.P M/hrs	P.E. rec. $	Total	Engrg (basic) M/hrs	Dev $	Tool-ing (BSC) M/hrs	P.E. non-rec. $	Fab M/hrs	Assy inst M/hrs	Mat'l $	O.P. M/hrs	P.E. rec. $	Total		
Non-recurring total																						
Dollars per – xxx units																						

Manhours

J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A

Actual cost collected

10 20 30 40 50 60 70 80 90 100

Design complete

Design changes included in estimate

Approvals	Title
Engrg	
Ops	
Mat'l	Model
Finance	

Figure 8.—Cost Target Sheet

Trade study request

Title

Purpose

Program ____________

No. ▷1 ____________

Date ____________

Revision ____________

Originator/Group ____________

Coordinator ____________ Phone ____________ Sheet ______ of ______

Work statement (describe for each participating group)

▷1 Sequential trade study number followed by suffix to indicate

C	—	Cost trade
C/W	—	Cost/Weight trade
T	—	Technical trade
W	—	Weight trade

Data req'd

- ☐ Engrg (design M/hrs)
- ☐ Fab, I&A (Manhours)
- ☐ P/N count
- ☐ Weight (lbs)
- ☐ Material ($)
- ☐ Quality
- ☐ O.P. ($)
- ☐ P.E. ($)

Est completion date ____________ Study authorized by: ____________

Recommended disposition

☐ Incorporate ☐ Cancel Project Engineer/Staff Chief ____________

Engineering management disposition

- ☐ Incorporate
- ☐ Cancel
- ☐ DDM required
- ☐ Revise config des doc
- ☐ Revise work pkg doc

Approved: ____________

Figure 9.—Design-to-Cost Trade Study Request

Trade studies are categorized as "process trade studies" (normally requested by manufacturing) or "design trade studies" (normally requested by engineering) and are assigned the following order of priority:

Priority	Type
1	Configuration trade (T)
1	Cost reduction trade (C)
2	Weight reduction trade (W)
3	Cost/weight trade (C/W)

The flow diagram for arriving at design decisions through the use of trade studies is shown by figure 10. The work package teams are charged with the responsibility of scrubbing down the system, subsystem, or design to meet or better the target cost and to resolve minor design-to-cost conflicts without resorting to formal trade studies. The iteration process is, however, recorded on the cost target sheet as a chronologically adjusted estimate as the design crystallizes. Where a cost conflict arises that cannot be resolved at the working level, manufacturing members will issue a formal trade study request.

4.2.1.6 Monitor and Control

It can be seen from the foregoing that the cost target sheet containing the baseline and the current estimate delta is the trackable element in the design-to-cost discipline. This is depicted graphically by figure 11.

Summary target and estimate delta data are compiled at WBS level 4 and up periodically (usually weekly) during the development program for presentation to the Design-to-Cost Manager and Review Board.

The degree of success in achieving design-to-cost is a reflection of the effectiveness of the work package team members and their line management. In recognition of this, they are staffed by experienced engineering and manufacturing personnel.

Management control and responsibility is vested in the design-to-cost manager, who identifies system and subsystem requirements that contain potential high-leverage cost elements and is the focal point for initiating alternate approaches or requirement changes to reduce cost estimates. He establishes a design-to-cost area in the program control room that displays current system, element, and functional progress in achieving the cost goal and that highlights actual and potential problem areas.

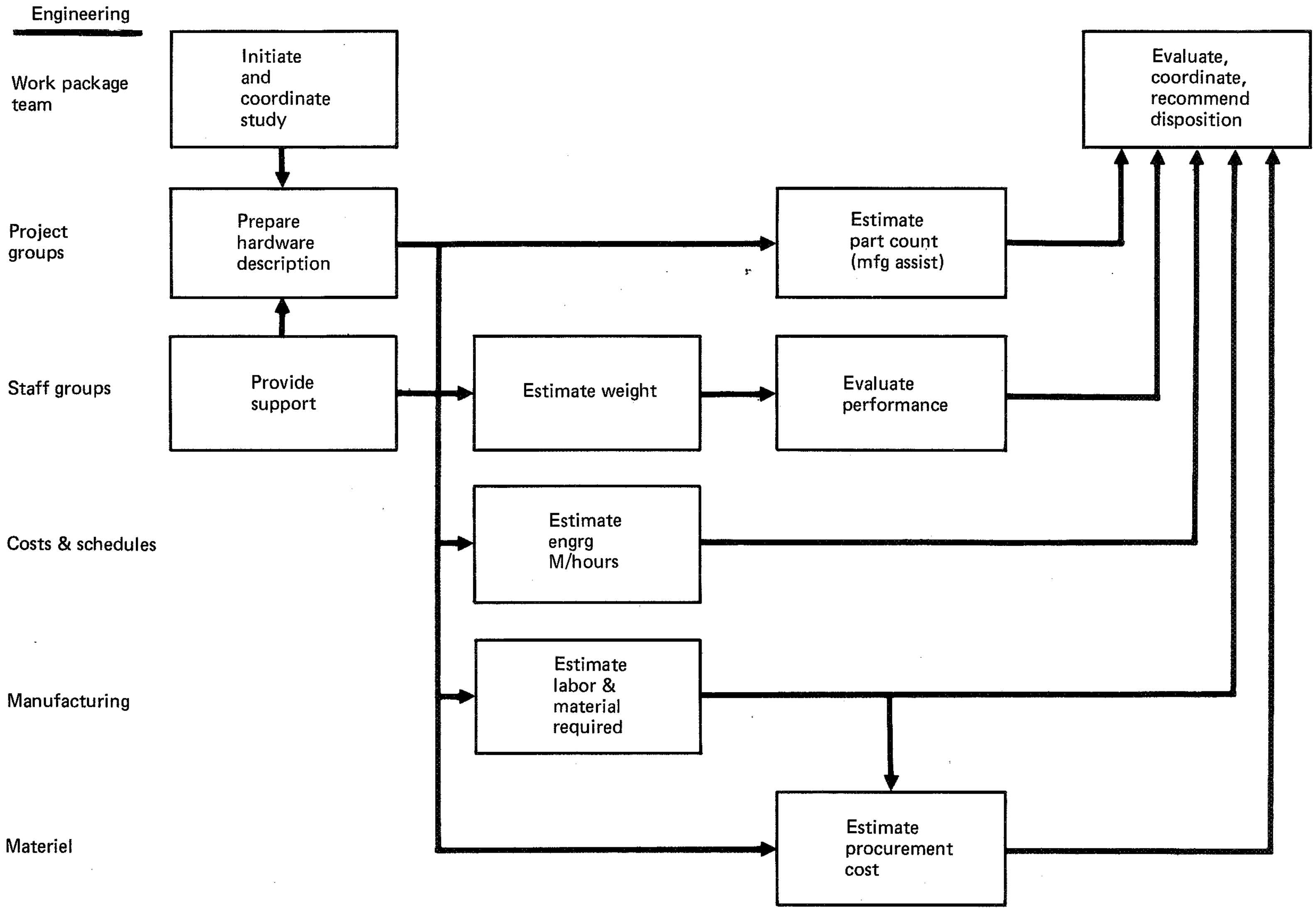


Figure 10.—Trade Study Flow

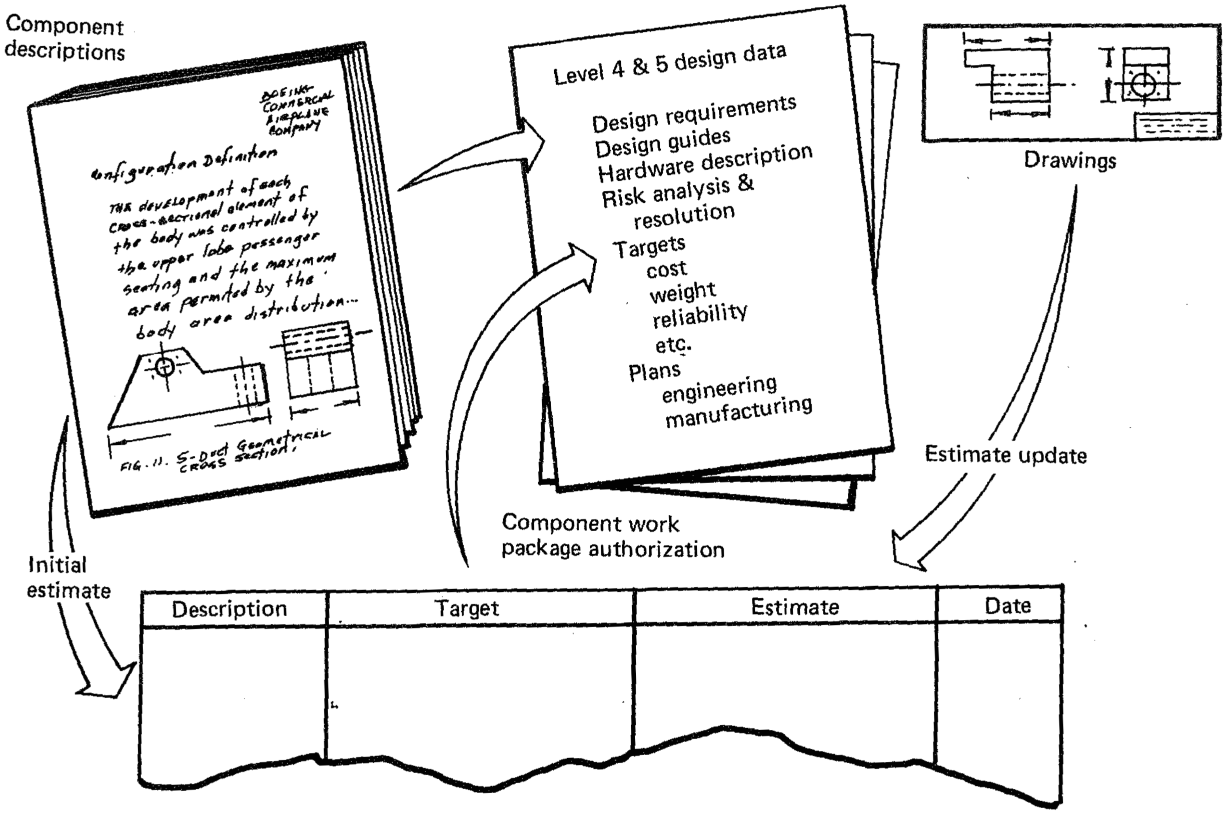


Figure 11.—Cost Target Development and Audit

This is achieved through the use of tracking charts showing the current and past estimate against the cost target.

The continuing iteration of the design by key personnel is the cornerstone of the cost-effective design. Their efforts are recorded by updated estimates on the cost target sheet. Formal iteration by trade study is documented. Each authorized trade study is assigned a sequential number and suffix for identification within the document which is a permanent record of trade study activity. Design-to-cost enforces the cost disciplines during the design development phase, which make the goals realistic. This premise is illustrated by figure 12. The concurrent development of the production tooling and planning with the development planning was discussed in section 4.2.1.3. The overall iteration and interplay between the work package teams and the Design/Cost Committee is depicted by figure 13.

4.2.1.7 Life-Cycle Costs

Cost targets (see sec. 4.2.1.4) include life-cycle costs and are based on product acquistion cost and product operational costs. Although design-to-cost has been primarily discussed within the context of reducing the cost of producing the system, the thrust of the discipline is inherently toward design simplicity such as part count reduction, the elimination of ornamental quality, and standardization. However, design simplicity is usually synonomous with reduced life-cycle costs and should be taken into account throughout all design development iterations.

4.2.1.8 Post-Development Programs

The ultimate objective of design-to-cost is to achieve the most cost-effective design prior to design release, which, in theory, eliminates any further downstream producibility application. However, during both preproduction and production programs, the estimates made during the development program are updated to reflect actual costs and are used to update the average production unit target cost. The same remedial measures discussed heretofore are applied as design changes are incurred.

Similar design-to-cost disciplines are applied to downstream design activities such as special tooling and special test equipment.

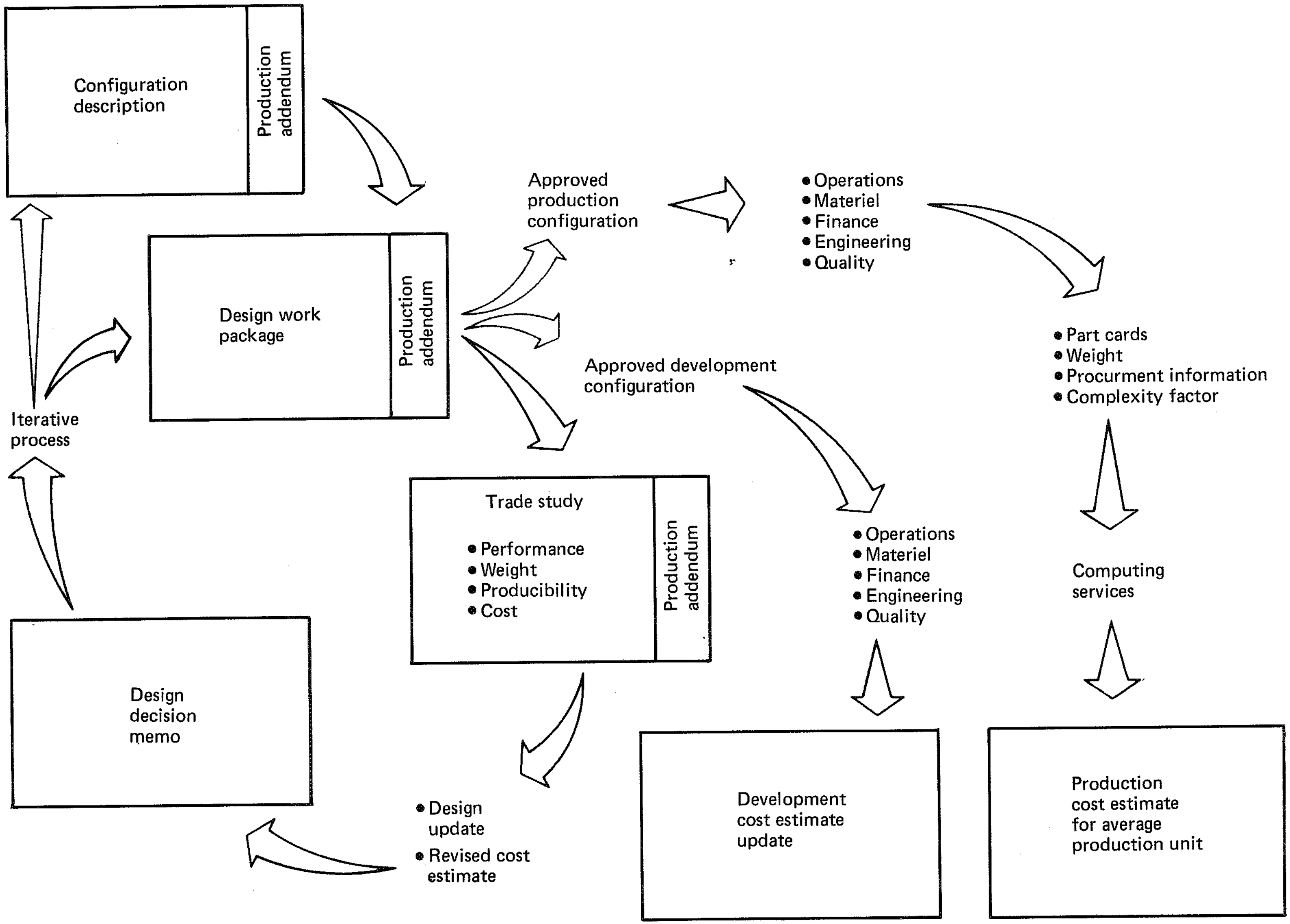
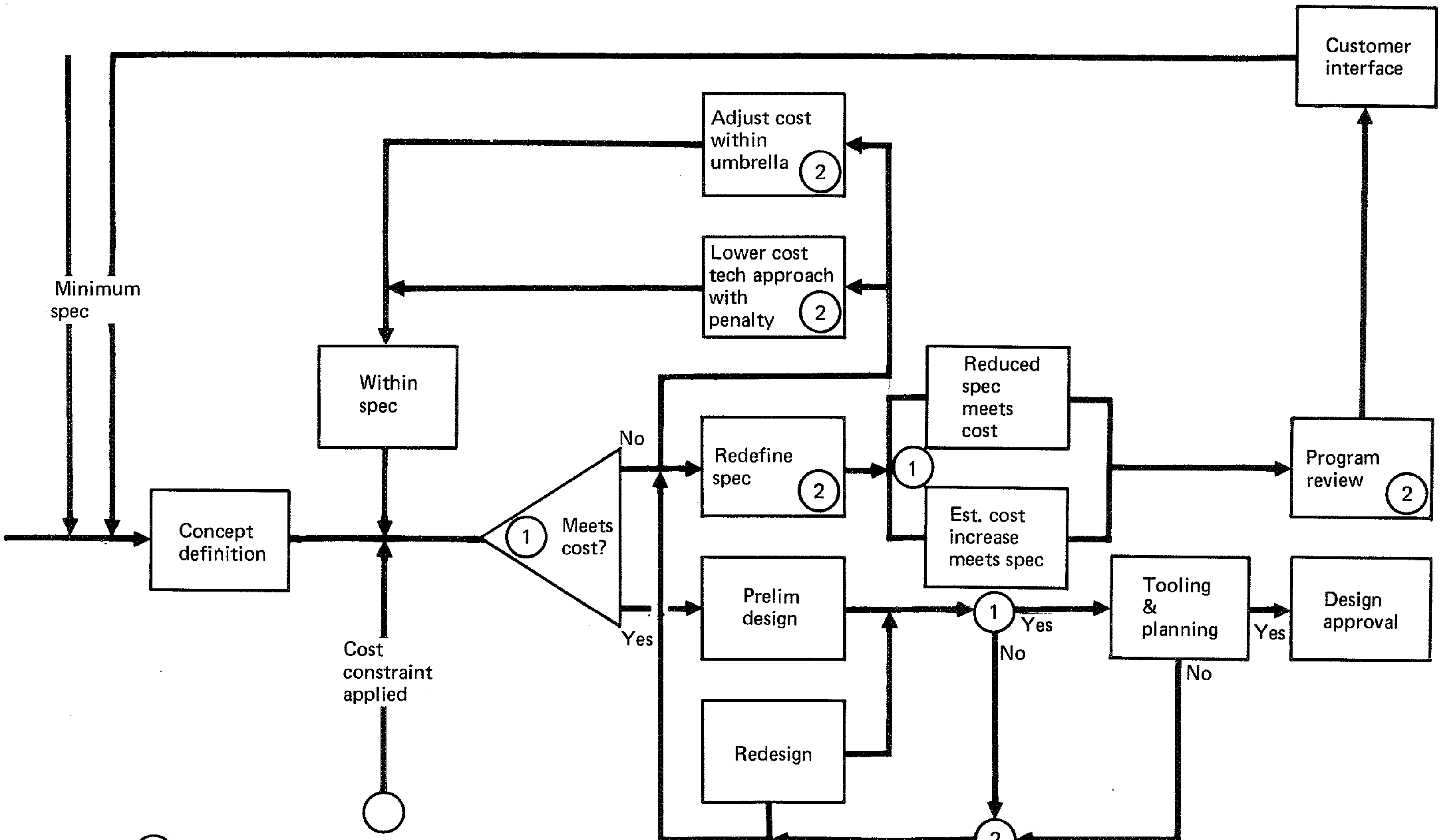


Figure 12.—Cost Management—Development and Production



1 Work package team (cost estimate)

2 Design-to-cost board (trade study and cost monitoring)

Figure 13.—Design-to-Cost Flow Control (Development Program)

4.2.2 DESIGN WORK PACKAGES

The design work package is an efficient tool to quickly acquaint the personnel assigned to the task with the task to be accomplished and with the applicable design requirements. It also provides early visibility of the component design approach and gives technology and manufacturing specialists an opportunity to make suggestions for cost and weight improvements.

The total product hardware is subdivided into discrete packages at WBS levels 4 and 5, and is organized as volumes of a document. Each volume is identified by the significant WBS code (sec. 4.1). The work packages will define the hardware, schedule, and critical events and will establish targets for the designer. Their purpose is to provide basic information for the design, development, and manufacture of the product and to serve as prime tools for:

Developing the complete component (element design)

Identifying potential product improvements including cost reduction

An up-to-date design description

Visibility of concept

Establishing and tracking targets

Providing up-to-date design review data

A tool for verification of compliance with design requirements and targets for each component design approach before detail design layout and drawing preparation

4.2.2.1 Work Package Content

Figure 14 portrays an overview of the design work package content and the program data from which the package is derived. The following are examples of work package content:

Design Requirements--An extract of the requirements for the particular WBS element from the total program design requirements and objectives

Design Guides--This section will include guides applicable to the work package based on historical experiences, such as structural durability handbooks, CAD indices, etc.

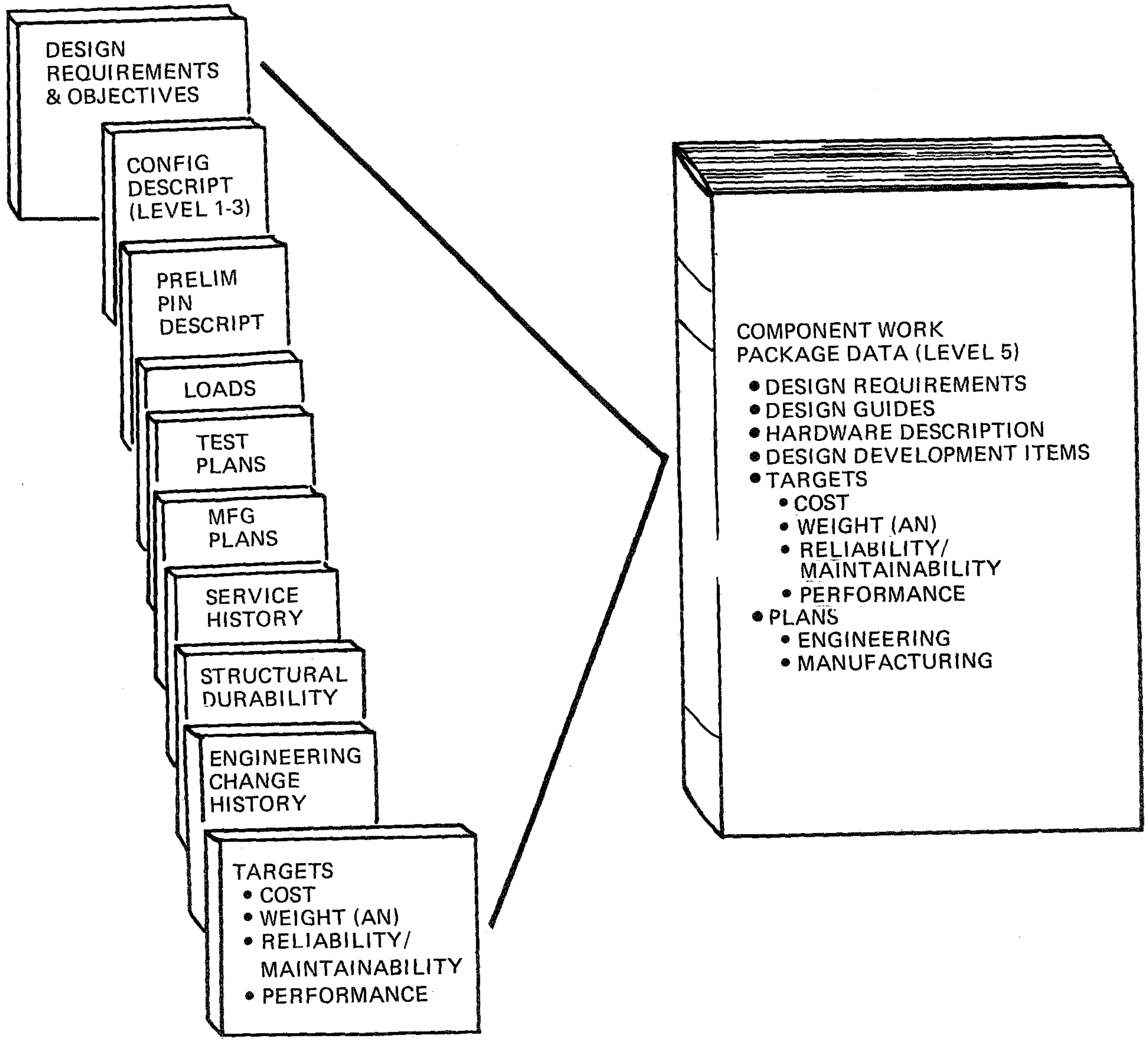


Figure 14.—Design Work Package Data

Hardware Descriptions--This section is a detailed description of the work package hardware and is the baseline description for trade studies. It consists of:

PIN Descriptions--detailed descriptions to the package WBS level and lower. (Figure 15 is an example of PIN description.)

Key Layouts--layouts, sketches and schedules, centerline diagrams, structural diagrams, etc.

Interface Requirements.

Design Development Items--This section is used to identify:

Unproven design concepts, materials, etc.

All tests to be conducted to arrive at a design decision

Special mockup requirements

Top priority items and plans and procedures for accomplishing these special attention items

Unique materials, processes, etc.

Targets--The section contains the targets and estimates per format (fig. 16). Weight, reliability, and maintainability targets are also included in this section.

Plans--This section contains the engineering plans and the manufacturing plan for first article.

4.2.3 WORK PACKAGE TEAM

The team is a dedicated group responsible for the contents of the work package. Members represent engineering (project and staff), manufacturing, materiel, and finance organizations. It is essential to success that team members be identified who will have the "doing" responsibilities. During the design phase, the project engineering member assumes the role of work package manager. After completion of design, the role is transferred to the manufacturing engineer. Figure 2.2.3-1 depicts the team makeup for several work packages. Section 4.2.1 (Design-to-Cost Plan) delineates the duties of the team.

Title: FRONT SPAR INST. - WING BOX

PIN ____________________

Sh ___ of ____________________

MATERIAL		PART TYPE		PART CARD QUANTITY
Ext		Sheet Metal		
SBT		Machined		
Std		Cast & Forg.		
Other		Assy. & instl.		
		Purchased		
		Other		

PARTS AND MATERIAL DESCRIPTION

Chords: For middle spar, segment will be angle extrusions machined 100% with constant flange angle for 423 in. length. Outboard segment chords will be angle extrusions machined 100% with flange angle varying throughout length of 570 ft. Chord material will be 7075-T73 (upper) and 2024-T2 (lower).

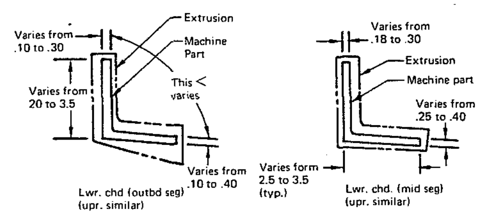
Webs: Will be broken into approximately 9 pieces, each of which will be constant gage 2024-T3. Total length = 1563 in. with width varying from 29 in. inboard to 7.0 in. at tip.

Doublers: Constant-gage doublers will be riveted to web at cutouts, etc.

Stiffeners: Approximately 181 extruded "Z" stiffeners will be used between inspar ribs and approximately 56 extruded "T" stiffeners will be used at inspar rib locations.

Fittings: Will be 7075-T73 hogouts with engine beam support fittings, per LO-953-W-050.

Note: 80% of all stiffeners are symmetrical.



ASSEMBLY AND INSTALLATION

The front spar is 1563 in. long and is made up of three segments. The middle segment is 423 in. long and has a constant depth of 29.2 in. It consists of 2 chords, web (3 pieces), 53 stiffeners, and 8 engine beam support fittings. The outboard segments are 570 in. long varying in depth from 29.2 in. inboard to 9.0 in. at tip and each consists of 2 chords, web (3 pieces), and 90 stiffeners. Spar will be assembled to panels by riveting with 3/16, 1/4, 5/16 and 3/8 dia. rivets from b.l. 211 to b.l. 632, spar will be sealed as an integral fuel tank.

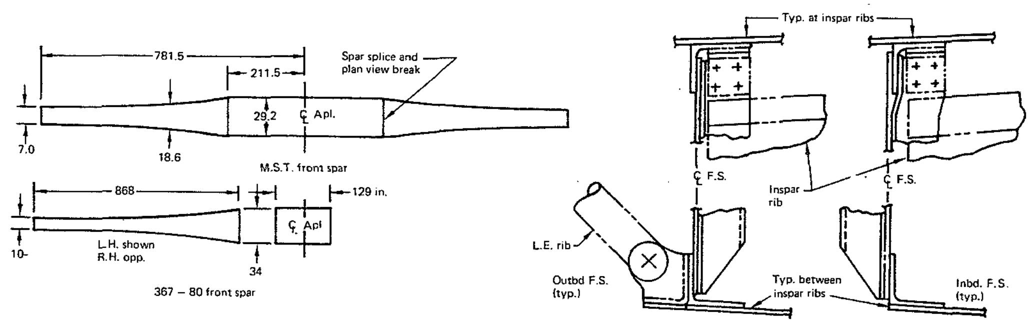


Figure 15.—Program Item Description

DESIGN PLAN

TITLE ______________________________ PIN ______________________

	ORIG	REV. A	REV. B	REV. C	REV. D
PROJECT					
STAFF					
MFG					

CALENDAR YEAR	1972		1973												1974												1975				TOTAL		REMARKS
MONTH/QUARTER	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	1st	2nd	3rd	4th	MANMONTHS	MANHOURS	
PROJECT MANPOWER SCH																																	
PROJECT MANPOWER ACTUAL																																	

KEY EVENTS	RESPONS
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	
11	
12	
13	
14	
15	
16	
17	
18	
19	
20	

AIRPLANE MAJOR MILESTONES — 100% RELEASE, RO, FF

Figure 16.—Design Plan Resource (Budget/Actual)

DESIGN WORK PACKAGE	SECTION/SYSTEM	ENGINEERING					MANUFACTURING			MATERIEL			QUALITY CONTROL
		PROJECT	AERO	STRUCT STAFF	SYST STAFF	WEIGHTS	MFG ENGR	TOOL ENGR	IND ENGR	SCHEDULE VISIBILITY	BAC CENTRAL	PROJECT	
	WING												
-112	WING TIP	W. BROWN	G. BEAN	R. SCHAAD		R. DEAN	D. FREEMAN	M. BREDVIK	G. MADLAND	R. L. WILES	J. L. SMITH	—	R. HUDSON
-112	STRUCTURAL BOX	W. BROWN	G. BEAN	R. SCHAAD		R. DEAN	D. FREEMAN	M. BREDVIK				—	H. HUDSON
-113	TRAILING EDGE	J. COLE	F. MAY	W. HANSEN	B. RAY	D. TURNER	S. MAJURY	M. BREDVIK				—	R. HUDSON
-114	LEADING EDGE	J. COLE	F. MAY	A. THORNTON	A. GUPTA/RAY	H. REITZ	M. GARNER	M. BREDVIK				—	R. HUDSON
	BODY												
-140-1	BASIC SHELL	C. ZEHNDER	G. BEAN	V. JOSENDAL		H. LEVY		M. WENGER				—	R. NYGREN
-140-2	CAB STRUCTURE & WINDOWS	C. MATTHEWS	G. BEAN	J. VICTOR	D. FADDEN	J. SAMMONS						R. C. WRIGHT	
-140-3	NOSE WHEEL WELL & BLKHDS	S. DANIGGELIS	L. DACOSTA	J. VICTOR		J. SAMMONS						—	
-140-4	FAIRINGS	A. BAILEY	G. BEAN	C. WEBB		H. LEVY	SEC. 41					—	
-140-5	DOORS, HATCHES & SUPT STR	M. MANCA	G. BEAN	G. ANDERTON	R. ABSHIRE	H. HEITZ	L.D. BROWN					—	
-140-6	WING & MLG SUPT STR	D. KNOPF		C. WEBB		J. SAMMONS	SEC. 43					—	
-140-7	FIN SUPPORT STRUCTURE	D. COOK	G. BEAN	P. CHRISTIE		J. FORBIS	E. THOMPSON					—	
-140-8	AFT CARGO DOOR, RAMP & SUPT STR	F. BARNES	G. BEAN	P. CHRISTIE		J. FORBIS	SEC. 46					—	
-140-9	IN-FLIGHT EMERG ESCAPE SYST	M. MANCA	G. BEAN	J. VICTOR	D. FADDEN	H. HEITZ	R. HUGHES					C. H. FORS	
-261	LANDING GEAR STRUCTURE	W. PLOMMER	F. MAY	R. JENSEN		D. TURNER						R. C. WRIGHT	
-242	CARGO & TROOP DELIVERY	E. WOODSON		V. JOSENDAL	D. FADDEN	H. HEITZ		M. WENGER				R. C. WRIGHT	R. NYGREN
	PROPULSION												
-160	STRUCTURE	M. STANLEY	F. MAY	G. BAILEY	C. GROTZ	S. CHAN	D. COOKSON	M. BREDVIK				R. C. WRIGHT	R. P. HUDSON
-316	FIRE PROTECTION	D. MILLER		P. HARRADINE	R. ABSHIRE	J. HUTTON	D. COOKSON	M. BREDVIK				D. D. DERHEIM	R. P. HUDSON
-313	EXHAUST SYSTEM	R. McCORMICK		G. BAILEY	R. HIRT		D. COOKSON	M. BREDVIK					R. P. HUDSON
-312	ENGINE	D. MILLER	F. MAY	G. BAILEY	R. HIRT	J. HUTTON	D. COOKSON	M. BREDVIK				R. C WRIGHT	R. P. HUDSON
	EMPENNAGE												
-170	VERTICAL TAIL	C. MYRON	G. BEAN	L. LIEFERMAN	B. RAY	J. FORBIS	G. RIPLEY	R. FULLER				—	R. NYGREN
-180	HORIZONTAL TAIL	C. MYRON	G. BEAN	L. LIEFERMAN	B. RAY	J. FORBIS	G. RIPLEY	R. FULLER				—	R. NYGREN
	MECHANICAL SYSTEM												
-210	ENVIRONMENTAL CONTROL	A. RAUDENBUSCH	G. BEAN	R. SEPPI	A. GUPTA	J. HUTTON	R. SCHUSLER	RELATED				D. D. DERHEIM	W. J. WAWRAK
-241*	CARGO COMPARTMENT	D. HOUCK		V. JOSENDAL	REID/FADDEN	H. REITZ	R. SCHUSLER	STRUCT				R. C. WRIGHT	W. J. WAWRAK
- 414	CARGO RAMP & DOOR ACT	R. COLLINS	G. BEAN	R. JENSEN	R. ABSHIRE	R. WATT	R. SCHUSLER					R. C. WRIGHT	W. J. WAWRAK
-2415	CREW ESCAPE & DEPRESS-	R. COLLINS	G. BEAN	R. JENSEN	E. REIQUAM	R. WATT	R. SCHUSLER					C.H. FORS	W. J. WAWRAK
-251	PRIMARY FLIGHT CONTROLS	D. KALIS	F. MAY	T. BYRSKI	FADDEN/KESTEK	R. WATT	E. BECKER					K. L. JORGENSEN	W. J. WAWRAK
-252	SECONDARY FLIGHT CONTROLS	D. KALIS	F. MAY	T. BYRSKI	FADDEN/[illegible]AN	R. WATT	E. BECKER					K. L. JORGENSEN	W. J. WAWRAK
-254	THRUST CONTROL SYSTEM	R. COLLINS	F. MAY		FADDEN/CARTER	S. CHAN	E. BECKER					K. L. JORGENSEN	R.P. HUDSON
-262	LANDING GEAR CONTROLS	R. SOUSLIN		R. JENSEN	R. ABSHIRE	R. WATT	J. BEGGS					R. C. WRIGHT	W. J. WAWRAK
-315	FUEL SYSTEM	E. OLSON	A. RENGSTORFF	BYRSKI/BAILEY	REIQUAM/TSUE	J. HUTTON	R. SCHUSLER					D. D. DERHEIM	W. J. WAWRAK
-330	HYDRAULIC SYSTEM	R. SOUSLIN		R. JENSEN	ABSHIRE/CHAN	R. WATT	J. BEGGS					C. H. FORS	W. J. WAWRAK
	AVIONICS/ELEC. SYSTEM												
-253	ELEC. FLIGHT CONTROL	E. ELLIOTT			FADDEN/MARTIN	J. HUTTON	H. HARRIS					K. L. JORGENSEN	W. J. WAWRAK
-270	AIRPLANE EXTERNAL	J. HURNER	G. BEAN		REIQUAM/RAY	R. WATT	H. BOEHME					R. C. WRIGHT	W. J. WAWRAK
-320	ELECTRICAL POWER SYSTEM	J. HURNER			REIQUAM/MARTIN	J. HUTTON	H. HARRIS					W. R. LANFEAR	W. J. WAWRAK
-220	AVIONICS	W. HUNSBERGER			FADDEN/MARTIN	J. HUTTON	G. WALLS	RELATED				W. R. LANFEAR	W. J. WAWRAK
-230	FLIGHT DECK	D. HOUCK			FADDEN/KESTEK	J. HUTTON	H. BOEHME	STRUCT	G. MADLAND	R. L. WILES	J. L. SMITH	W. R. LANFEAR	W. J. WAWRAK

Figure 17.—Work Package Teams

4.2.4 PRODUCT COST CONTROL

Since up to 80 percent of a program cost is committed before first detail drawing release, it is mandatory that a credible cost targeting, estimating, and tracking system be implemented early in a program. The cost system described in this section is based on detail-estimating the hardware costs of designs of functional components of the airplane at WBS level 5 and lower. Verification of these estimates is then accomplished by comparing them to costs of components for which good hardware cost, operating costs, and performance history are available.

Cost surveillance and reduction is a continuous process. The cost data estimated by feature are adapted to an organization accounting system to assign cost targets to each engineering, manufacturing, and materiel organization that contributes to the end item cost. Maintainability and reliability are targeted and tracked in much the same manner. All these, together with budgets, are arranged in the work breakdown structure to roll up from WBS level 5 (spars, wing, TE flaps, etc.) thus providing a very simple responsive audit system (fig. 18). It is expected that program management hardware cost reviews will be conducted monthly and budget reviews weekly.

4.2.4.1 Definitions

Parametric Estimate--An estimate is made of the "probable" cost of an airplane using gross parametrics, appropriately adjusted, based on historical statistics (performance, weight, etc.).

Class I Estimate--A detail cost estimate is made of what the airplane "should" cost, based on preliminary hardware descriptions to the work package level. Class I estimates provide realistic bases for class II targets.

Class II Estimate--A detailed cost estimate is made of what the airplane "should" cost based on refined engineering data such as detail layouts and WBS level 5 work package data. It is used to verify the hardware cost status as compared to the pre-established class II design cost targets. Engineering detail "design-to-cost" and manufacturing performance are measured against class III cost targets for in-process cost visibility.

Class III Costs--This is the actual hardware costs as accumulated by finance, including material, fabrication, minor assembly, and major assembly.

- SIGNIFICANT NUMBERING SYSTEM FOR CROSS ORGANIZATION COMMUNICATION
  - ENGINEERING (DESIGN PACKAGE IDENT, PLANNING, SCHEDULING
  - MANUFACTURING (PLANNING, KITS, TOOLING, ETC)
  - FINANCE (COST COLLECTION, REPORTING)
  - BUSINESS MANAGEMENT (BUDGET ALLOCATION, REPORTING)
- AUTDIT TOOL
  Σ THRU SIGNIFICANT CODE FOR:
  - BUDGET (CSCSC)
  - COST
  - RELIABILITY/ MAINTAINABILITY
  - PERFORMANCE
  - SCHEDULES

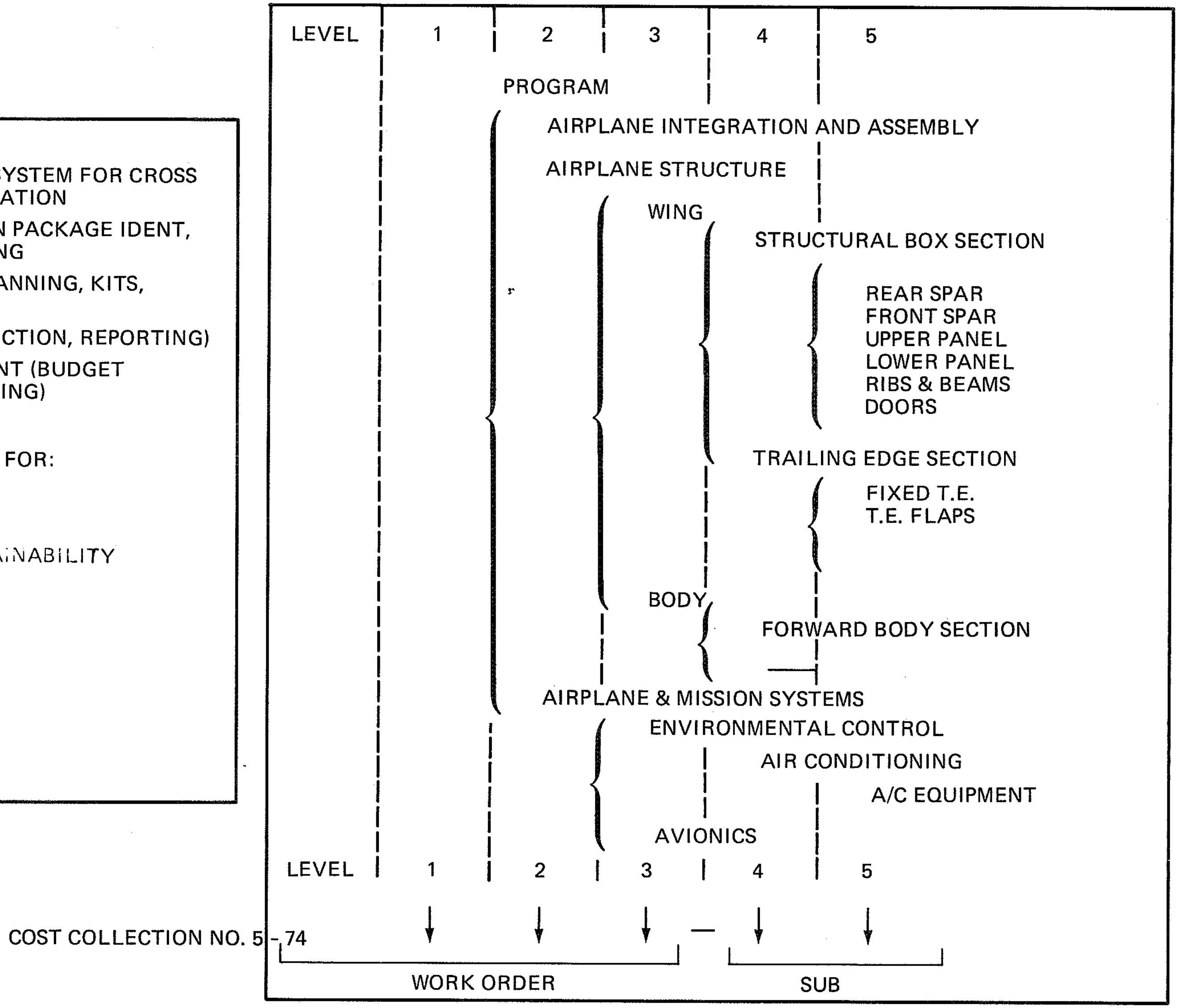


Figure 18.—WBS: A Single Management Tool

Probable Cost--This is a parametric estimate of the anticipated program cost based on historical relationships adjusted for weight, complexity, and commonality.

"Should" Cost--This is the calculated value of the hardware based on a standard derived from actual experience and computed after completion of a series of trade studies.

4.2.4.2 Cost Model

Programs costs consist of recurring and nonrecurring hardware and program support costs. (See table 1).

Table 1.--Program Cost Model

	RECURRING	NONRECURRING
HARDWARE COSTS	Production labor: Fabrication Minor assembly Major assembly Related mat'l. Quality control in support of prod. labor Purch. equip. Direct labor fringe benefits Incremental overhead	Basic engineering (including component tests) Basic developmental mockup, test, and related materials Basic tooling and related materials Basic tool and production planning Prod. mat'l. (less static and fatigue) Purchased equipment Quality control labor in support of above Direct labor fringe benefits Incremental overhead
PROGRAM SUPPORT COSTS	Eng. sustaining Devel. mockup Tooling sustaining plus related materials Rework, special charges, and prod. planning QC labor in support of above Purch. equip. develop. costs Engines Buyer-furn equip Direct charges Fixed overhead	Engineering administration, laboratories, and customer support Flight test Major tests, customer support, flight test, and related materials Tool and production planning for static and fatigue testing Production labor and mat'l. for above Purchased equipment development costs QC labor in support of above Direct charges Fixed overhead

4.2.4.3 Development Sequence

The development sequence of the design data and cost estimate requirements is illustrated in figure 19.

4.2.4.4 Cost Target Development

A total program competitive cost is determined, based on historical data and market research and analysis. The program manager establishes a total program cost target. Using historical actual costs, he allocates targets to the WBS level 2 elements. Each functional discipline, in turn, allocates his targets to at least WBS level 5. (See fig. 20.)

The cost targets are recorded on the cost target tracking form (fig. 16) in each work package document (sec. 4.2.2.1). Detail cost estimates are made and iterated based on the detail program item number (PIN) descriptions.

4.2.4.5 Cost Target Audit Cycle

Figure 21 depicts the iterative process. An overview of the targeting/tracking/cost audit cycle and sequence is shown in figures 22 and 23.

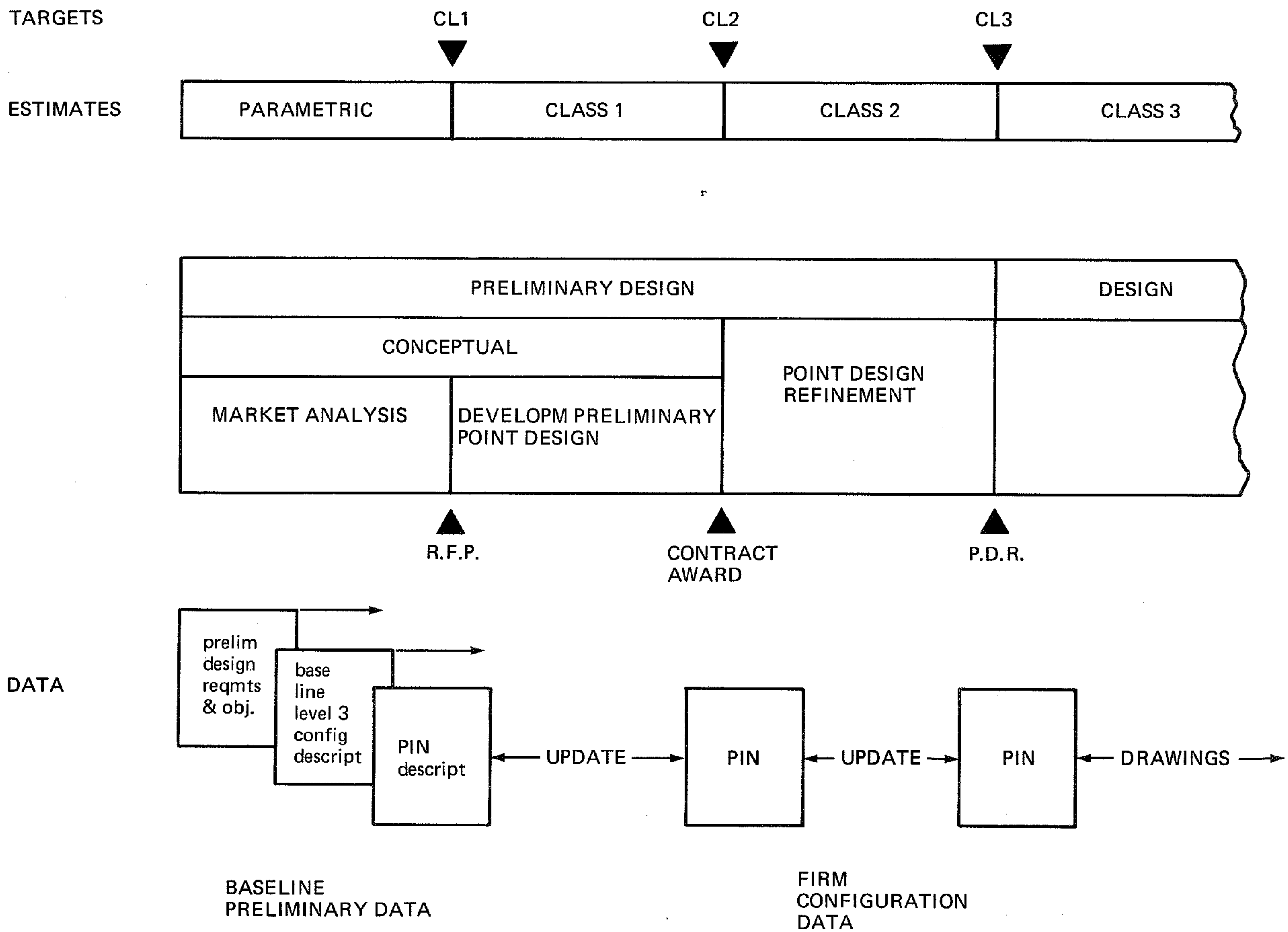


Figure 19.—Design Data and Cost Estimate Refinement

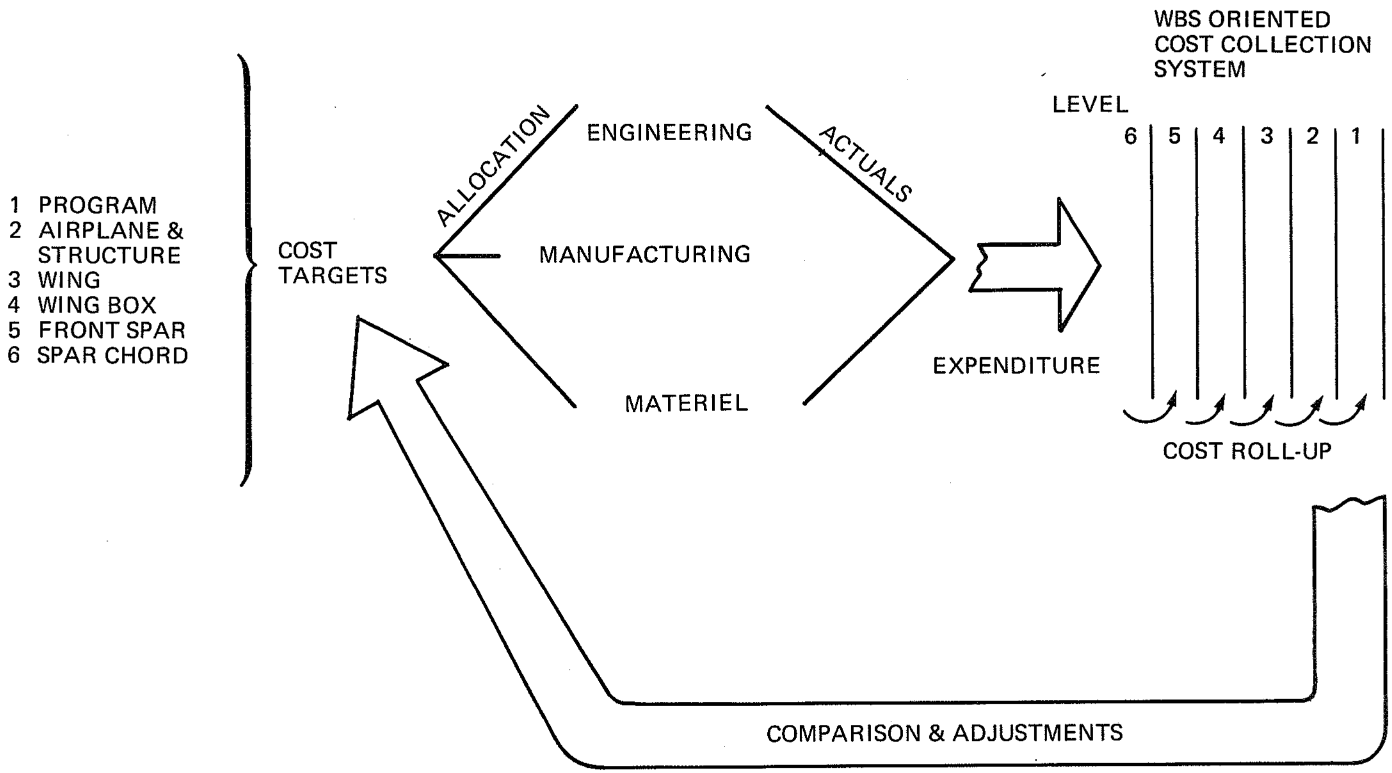


Figure 20.—Work Package Cost Allocations/Budgets

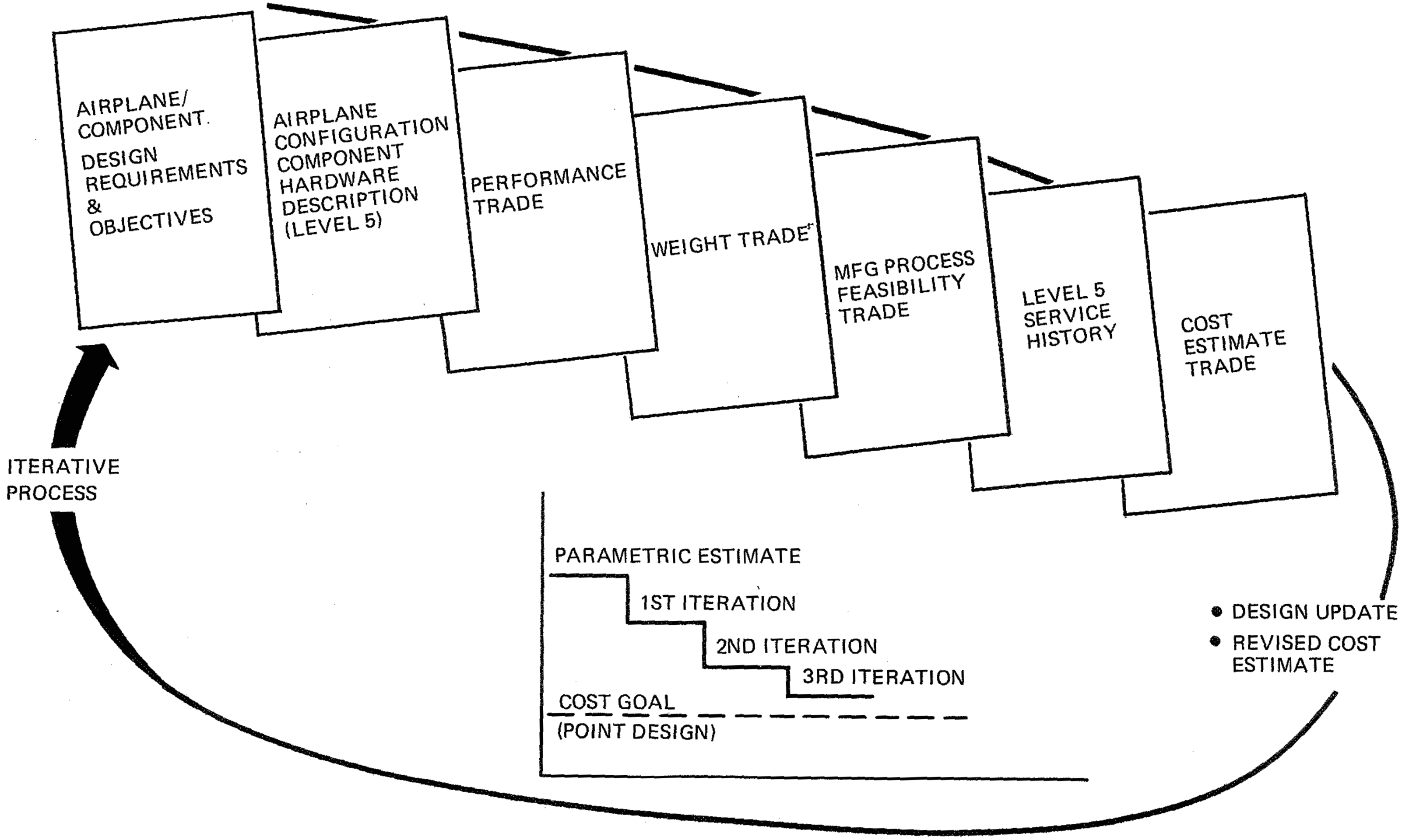
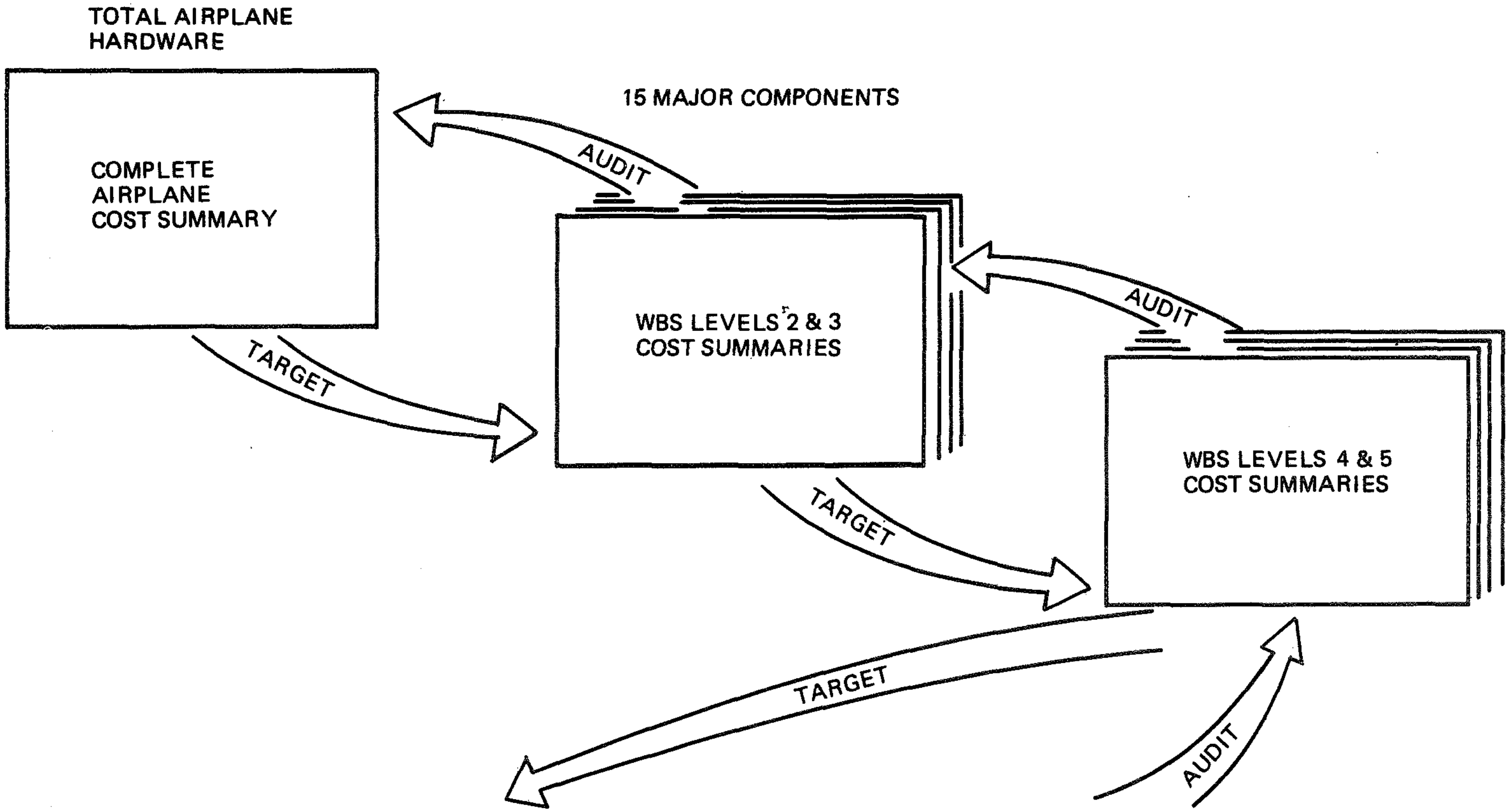
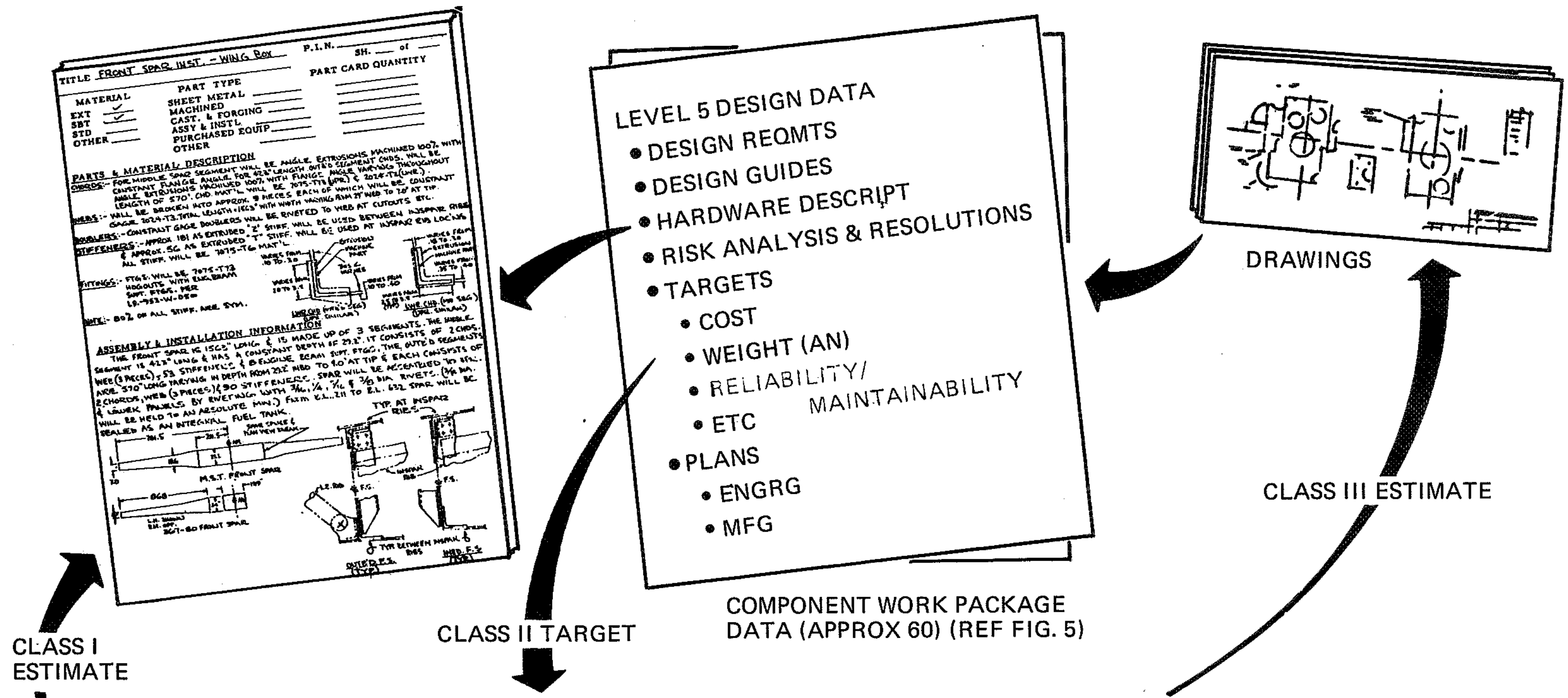


Figure 21.—Iterative Process



DESCRIPTION	TARGET										ESTIMATE NO.					DATE						
WBS ELEMENT	TOTAL				COST PER AIRP BASED ON AIRPS						TOTAL				COST PER AIRP BASED ON AIRPS							
	ENGRG (BASIC) MN-HRS	DEV $	TOOLING (BASIC) MN-HRS	P.E. NON REC. $	FAB. MN-HRS	ASSY AND/OR INSTL. MN-HRS	MATL. $	O.P. MN-HRS	P.E. REC $	TOTAL	ENGRG (BASIC) MN-HRS	DEV $	TOOLING (BASIC) MN-HRS	P.E. NON REC. $	FAB MAN-HRS	ASSY AND/OR INSTL MN-HRS	MATL. $	O.P. MN-HRS	P.E. REC $	TOTAL	UNDER TARGET	OVER TARGET
NON-RECURRING COST TOTAL																						
COST PER AIRP BASED ON AIRPS																						

Figure 22.—Cost Targeting and Tracking by WBS



DESCRIPTION	TARGET										ESTIMATE NO.				DATE							
WBS ELEMENT	TOTAL				COST PER AIRP BASED ON AIRPS						TOTAL				COST PER AIRP BASED ON AIRPS							
	ENGRG (BASIC) MN-HRS	DEV $	TOOLING (BASIC) MN-HRS	P.E. NON REC. $	FAB. MN-HRS	ASSY AND/OR INSTL. MN-HRS	MATL. $	O.P. MN-HRS	P.E. NON REC $	TOTAL	ENGRG (BASIC) MN-HRS	DEV $	TOOLING (BASIC) MN-HRS	P.E. NON REC. $	FAB MAN-HRS	ASSY AND/OR INSTL MN-HRS	MATL. $	O.P. MN-HRS	P.E. REC $	TOTAL	UNDER TARGET	OVER TARGET
NON-RECURRING COST TOTAL																						
COST PER AIRP BASED ON AIRPS																						

Figure 23.—Cost Audit Cycle

5.0 SCHEDULE MANAGEMENT

A master schedule is used as the baseline for the total program. It contains the key milestones and constraints from all disciplines, including the customer. The schedule should be based on proven experience and should be developed to permit an optimum balance between technical and cost performance. Management of the schedule acknowledges that variances require compensation in order to protect cost and technical objectives.

5.1 SCHEDULE CONTROL

Schedule control is based on a hierarchy of tiered schedules (fig. 24), which are generally aligned to work breakdown structure (WBS) levels. Tier I is the program master schedule; it covers all elements of the program and is approved by all functional organizations. Tier II consists of program element schedules. They cross functional lines and provide visibility of functional schedule integration. Tier II schedules are used to analyze and resolve program schedule problems. Tier III and lower schedules show functional responsibility. For cost/schedule correlation, individual functional schedules are associated with specific packages of work having specific budgets. Functional schedules aid in the development and substantiation of program schedules. They include both "work-oriented" and "milestone-oriented" types.

The lowest tier is the integrated engineering schedule. It identifies and defines the schedule relationships between the technical tasks to be performed by the various design project groups and the technology staff groups during the basic design process. The purpose is to assure schedule integration between those tasks which are highly interdependent in terms of technical data availability and timely performance of design and technical tasks relative to data. Integrated engineering schedules set forth the major milestones representing the following schedule dependencies:

Design project group schedule requirements for key interface design data from another design project group upon which their effort depends

Design project group schedule requirements for key technical data from a technology staff discipline group upon which their design effort depends

Technology staff discipline group schedule requirements for key design data from a design project group upon which their technical tasks depend

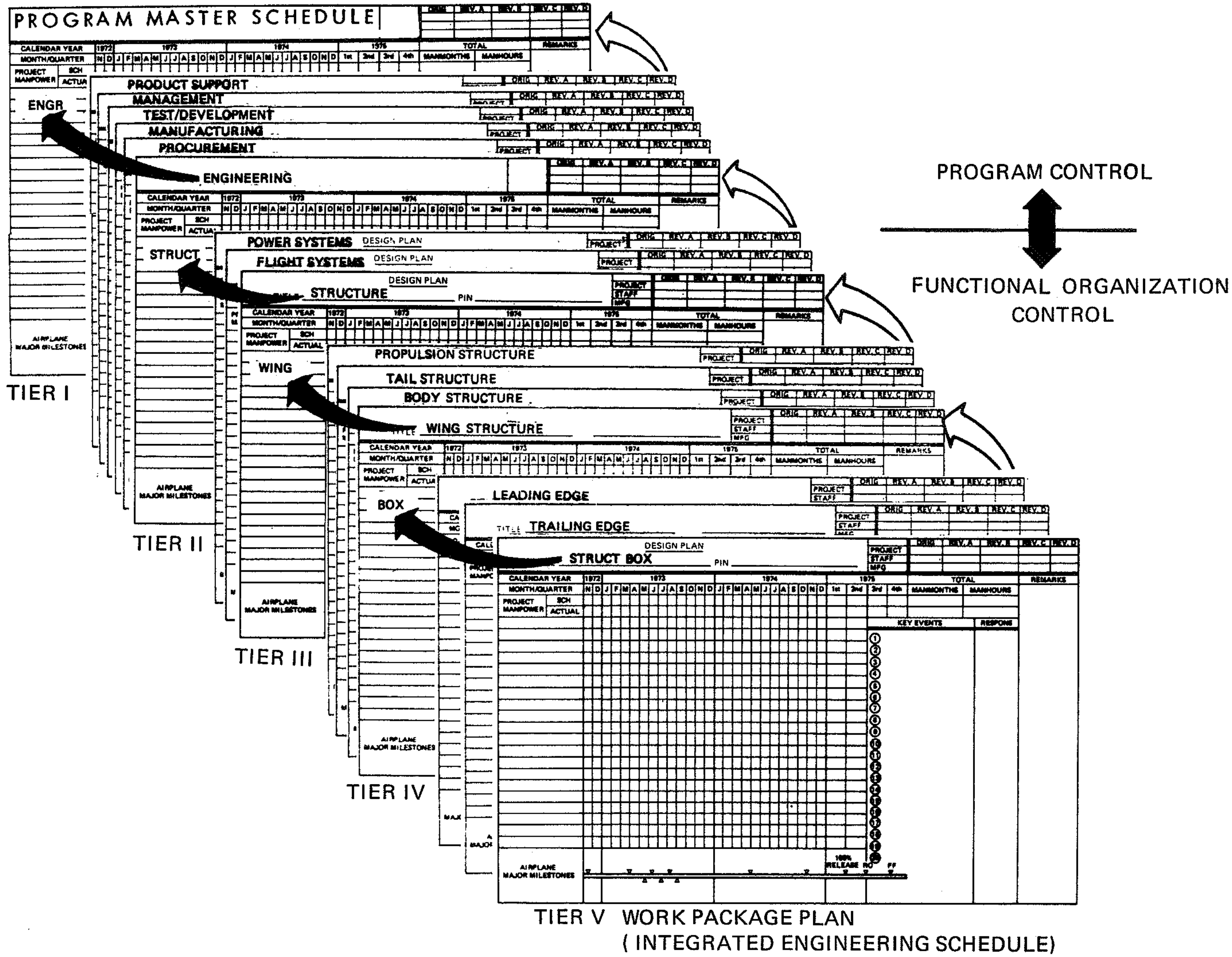


Figure 24.—Schedule Hierarchy

Technology staff discipline group schedule requirements for key technical data from another technology staff discipline group upon which their technical tasks depend

Effective scheduling of these engineering activities, in successive levels of detail as required, substantially increases effectiveness of the overall engineering design process.

Engineering data release dates to support program schedules are negotiated between engineering and manufacturing and are subsequently input into the data storage and retrieval system.

5.2 SCHEDULE REPORTING

The purpose of the engineering schedule reporting system is to:

Provide a centralized source for schedule and status control, on a regular cycle, utilizing automatic data processing equipment

Provide total visibility of scheduled engineering milestones

The schedule reporting requirements and formats are covered in section 9.0 "Engineering Performance Reporting."

6.0 RESOURCE MANAGEMENT

The program manager is responsible for control of program funds authorized by company headquarters. During the product technical definition phase, he receives from his functional chiefs their requirements for resources such as manning, skill mix, and facilities.

6.1 RESOURCE CONTROL

The WBS (sec. 4.1) is the tool used to plan, control, and report activities such as budgets, costs, schedules, performance, facilities, and travel.

The program manager, with the aid of his functional advisors, establishes targets for the major disciplines (engineering, manufacturing, materiel, finance, facilities, etc.) based on historical information and the requirements inputs. Each functional discipline, in turn, allocates his targets to the lowest manageable WBS level in his area of responsibility.

6.2 RESOURCE REPORTING

During the program, actual expenditures plus estimates to complete are collected and rolled up to the program level. These are displayed in the visibility room (sec. 10.0). The estimates are compared to the targets and the targets are adjusted as required. Figure 25 depicts the process and is similar to the original targeting shown in figure 20.

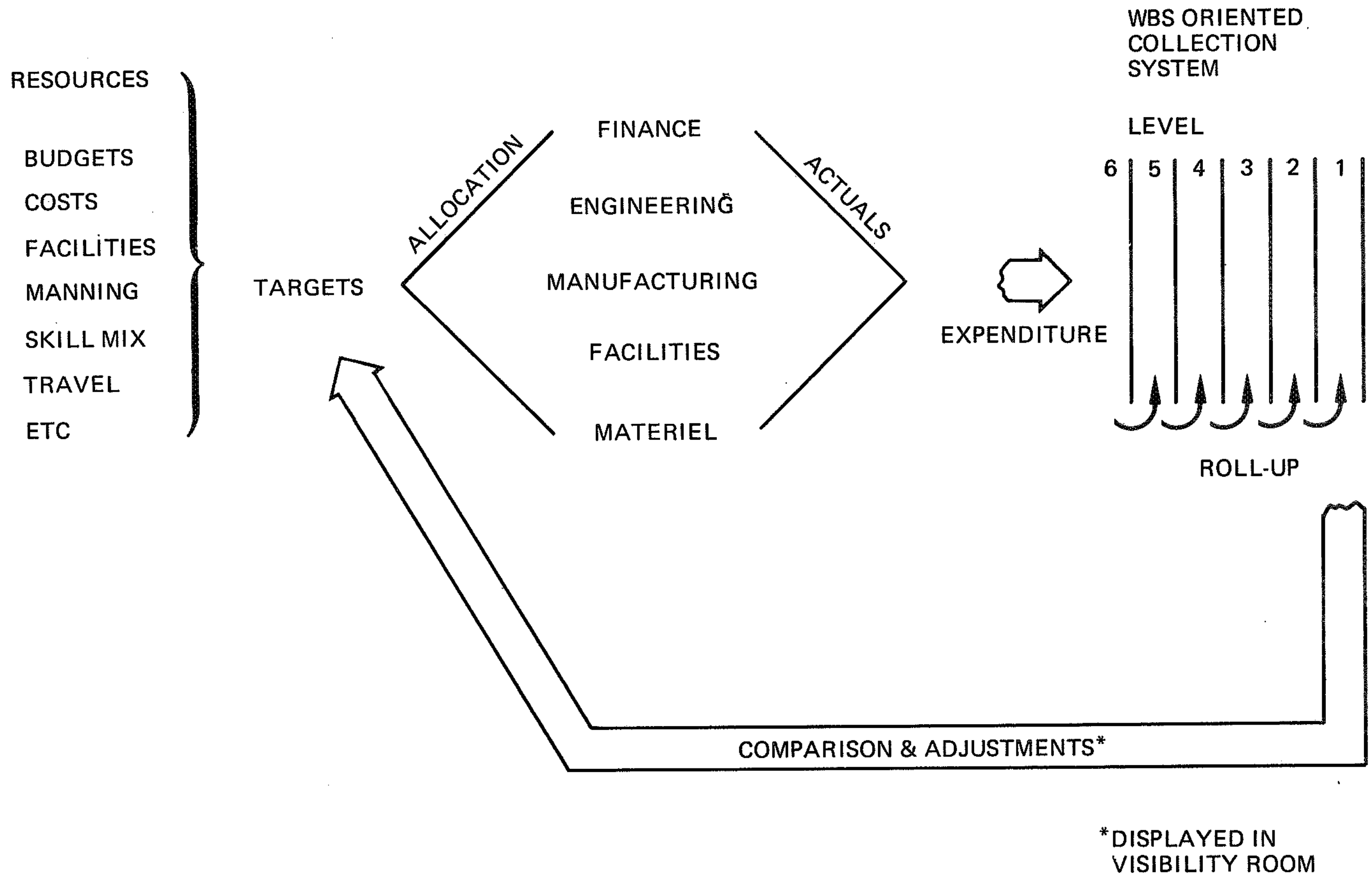


Figure 25.—Resource Control

7.0 CONFIGURATION MANAGEMENT

Configuration management on a program is the continuing process by which the configuration of the product is defined and controlled throughout its design, manufacture, test, and delivery. Configuration management is one of the most important management processes used on the program, ensuring that the product configuration delivered to the customer represents what he contracted for and that the configuration of parts, systems, subassemblies, and assemblies are to the desired configuration at all steps of production. On a program where the design, manufacture, procurement, and test work will be widely dispersed among program organizations and subject to complex communication channels, effective configuration management is essential.

7.1 PRINCIPAL CONCEPTS

7.1.1 CONFIGURATION DEFINITION AND IDENTIFICATION

This concept involves the management controls which describe and identify the product configuration. The controls applied to this aspect of configuration management assure that: (1) the configuration is defined in accordance with established methods of identification, (2) the configuration is documented and officially established by management approval, and (3) the configuration satisfies the established customer and design requirements, including those of Government regulatory agencies.

7.1.2 CONFIGURATION CHANGE CONTROL

This concept refers to the systematic evaluation, coordination, and approval or disapproval of proposed changes to the design and manufacture of the configuration. It is a continuing function extending from early design definition throughout hardware production.

7.1.3 PRODUCTION CONFIGURATION ACCOUNTABILITY AND CONTROL

This concept involves the management controls and paperwork systems that carry the intended configuration established by the designer forward into the released engineering data, manufacturing data and procurement data so as to reflect the proper hardware and software configuration, including authorized changes.

7.1.4 PRODUCTION CONFIGURATION VERIFICATION

This concept refers to quality control and procedures that: (1) verify the actual "as-built" configurationof each production unit delivered to a customer and (2) account for completed hardware records relative to the configuration "as designed" by engineering and "as planned" by manufacturing engineering.

7.1.5 INTERFACE MANAGEMENT

This concept refers to the controls and procedures that ensure physical and functional configuration integrity between mating hardware elements. This involves configuration identification, change control, and verification as applied to the physical, functional, and environmental interfaces between work package end items assigned to different program organizations for design, manufacture, or procurement. The principal applications of these procedures occur during design and development, when all interfaces must be identified and defined and their configuration characteristics must be properly incorporated into the design of the mating elements.

7.2 PRODUCT TECHNICAL DEFINITION PROCESS

During the product technical definition process, the product configuration is developed and defined in accordance with the configuration identification requirements. Figure 26 illustrates the product technical definition process. This process extends through the early program phases, from the conceptual development phase and the preliminary design phase to the engineering design and development part of the production phase. During each of these phases, the engineering design and configuration development leads to an appropriate configuration definition represented by the required technical documentation, drawings, and data.

A configuration definition baseline is developed for initiating the preliminary design phase. This baseline for preliminary design results from the techical concept and configuration development work and airline contacts during the conceptual development phase. It represents the basic product to be offered to the airlines and is defined in the design data document and the standard detail specification. It is the foundation for the technical and planning work performed during the preliminary design phase.

The second baseline--which is developed for go-ahead--results from the further configuration definition, design, and marketing/sales activities during the preliminary design phase leading to the first customer sale and an engineering detail design go-ahead. These activities include establishing the

updated standard detail specification; the customer detail specification, which defines the specific airplane purchased; the purchased equipment document; the program item number (PIN) document; and the work package design specification, which provide configuration definition data as part of the work packages.

This baseline represents the configuration that will be developed in detail during the engineering detail design process.

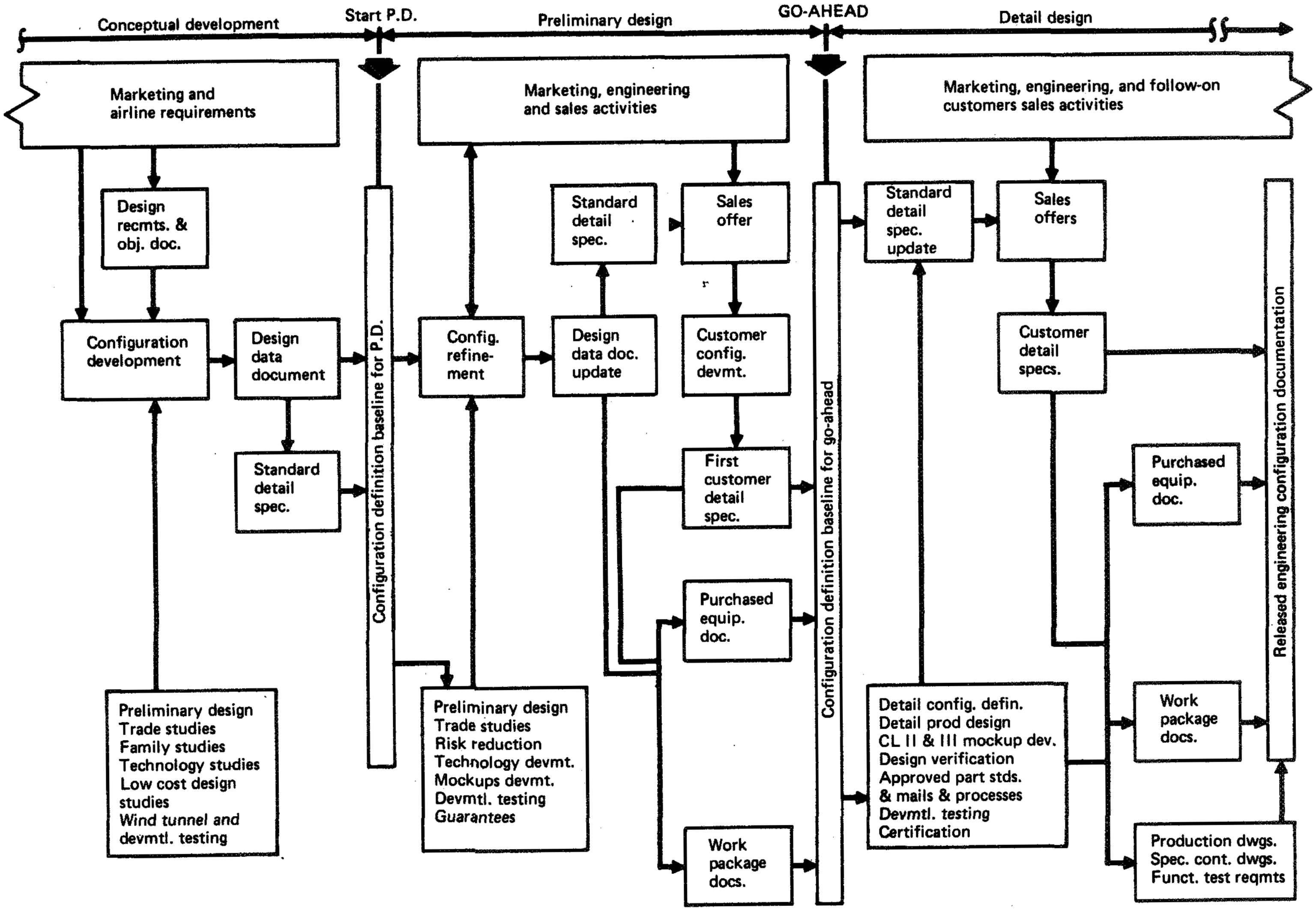


Figure 26.—Product Technical Definition Process

A program go-ahead initiates the production phase. This phase consists of the design development, test, and release of engineering drawings that comply with specific customer contractual requirements. The initial production phase configuration is based on the standard detail specification, and the customer detail specification resulting from the preliminary design phase, as well as the other engineering documentation.

This configuration is established incrementally by release of engineering data within each organization in accordance with the program release schedules.

7.3 CONFIGURATION MANAGEMENT--PRODUCT TECHNICAL DEFINITION PHASE

Figure 27 illustrates the basic flow of configuration management during product technical definition shown in terms of: 1) major program milestones, 2) the configuration definition and identification activities, and 3) the configuration baseline documentation in each case. The time-phased relationships among these elements substantially define the functions of configuration management during the evolutionary product definition process in the early phases of the program.

7.4 CONFIGURATION CHANGE CONTROL--PRODUCT TECHNICAL DEFINITION PHASE

Figure 28 illustrates the basic concepts of configuration change control during the early program phases. The curve in the center of the chart illustrates the release of engineering data beginning during the conceptual development phase. At this point, formal change control is initiated utilizing the configuration change control media indicated at the bottom of the chart.

As the product definition process continues, additional documentation is developed and released. The configuration identification and definition contained in the baseline documentation is subject to an increasing level of configuration change control as the definition process continues. Thus, as the amount of technical definition documentation released increases, the degree of formal configuration change control increases proportionately.

	CONCEPTUAL DEVELOPMENT PHASE	PRELIM DESIGN PHASE	PRODUCTION PHASE
CONFIGURATION MANAGEMENT BASELINES	P.D. CONFIG BASELINE ▼	▼	CONFIGURATION BASELINE FOR GO-AHEAD
CONFIGURATION DEFINITION & IDENTIFICATION ACTIVITIES	• CONCEPT & CONFIGURATION DEVELOPMENT • PRELIMINARY DESIGN TRADE STUDIES • LOW COST DESIGN STUDIES • AIRLINE CONTACTS • DESIGN DATA DOCUMENT DEVELOPMENT • WIND TUNNEL & DEVELOP TESTING	• DESIGN CONFIG DEFINITION • STD CUSTOMER SPECS DEV • PIN & PURCH EQ DOCUMENT DEV • WORK PKG DOCS DEV	• DETAIL DESIGN, REVIEW & RELEASE • CLASS II & III MOCKUP DEVELOPMENT • PARTS, STDS, MATERIALS & PROCESSES VERIFICATION & INDEXING • CUSTOMER NEGOTIATION • DESIGN IMPROVEMENT
CONFIGURATION BASELINE DOCUMENTATION	• DESIGN DATA DOCUMENT • DESIGN REQUIREMENTS & OBJECTIVES DOCUMENT ▼	• STANDARD DETAIL SPEC • DESIGN DATA DOC • CUSTOMER DETAIL SPEC • PIN DOC • PE DOC • WORK PKG DOCS • CHANGE REQUEST DOC ▼	• STANDARD DETAIL SPEC • CUSTOMER DETAIL SPEC • PRODUCTION DRAWINGS • SPEC CTRL DWGS • MANUFACTURING ACCOUNTABILITY LISTS • CONFIGURATION ACCOUNTABILITY MFG ENGR DOCUMENT • PE DOC • PIN DOC • WORK PACKAGE DOC

Figure 27.—Configuration Management During Product Technical Definition Phase

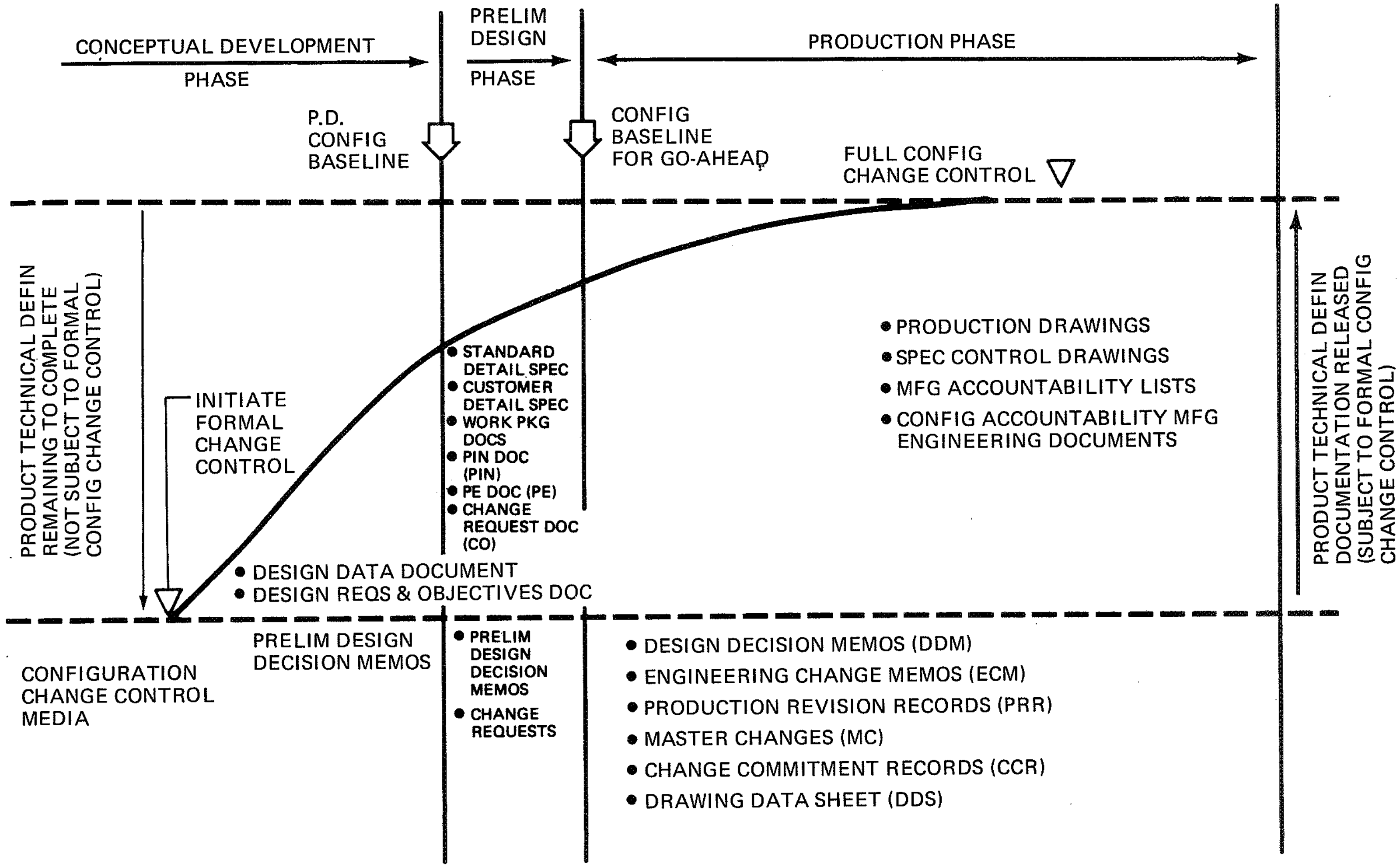


Figure 28.—Configuration Change Control During Product Technical Definition Phase

7.5 CONFIGURATION ACCOUNTABILITY AND VERIFICATION--PRODUCTION PHASE

As engineering configuration data and subsequent design changes are released to the manufacturing process, the integrity of the configuration will be maintained throughout the engineering release function and the downstream functions of manufacturing and procurement.

As the production program progresses through new customer introductions--each involving new and different configuration requirements--the design, manufacturing, and procurement paper systems will accurately reflect the many hardware configuration changes between units in the production process. As engineering design changes are implemented, additional changes will be accounted for in these paper systems to ensure that the hardware will be procured or manufactured in the proper configuration for each unit.

The configuration accountability process provides the foundation for configuration verification by assuring that the design, manufacturing, and procurement paper reflect the proper configuration of the hardware. It makes possible the comparison and verification of the hardware configurations with the mating paper configuration definition. Verification records are required at all levels from detail parts to the complete airplane.

The responsibility for establishing and implementing configuration verification procedures, based on established configuration accountability systems, rests with organizations where the design, manufacture, or procurement responsibilities are assigned for each work package.

7.6 CONFIGURATION CHANGE CONTROL--PRODUCTION PHASE

There are two purposes for configuration change control during the production program. The first is to ensure continuous integrity of the design configuration at all stages of production--detail parts, subassemblies, major assemblies, and complete airplanes. The second purpose is to maintain effective management control of program costs and schedules related to incorporation of engineering design changes.

All design changes are implemented at the "doing" organization level by change commitment implementation procedures. Some design changes will impact more than one work package and, therefore, more than one "doing" organization. Such changes will require coordination between the affected "doing" organizations. Their commitment and implementation activities must be integrated by a Change Commitment Board. Some design changes require negotiation and approval by the customer or a governmental

regulatory agency. All changes will be accomplished in accordance with approved procedures.

Configuration change control procedures are designed to ensure that: 1) all program organizations use compatible procedures, 2) control is maintained on design changes, and 3) the potential downstream impact of a change is coordinated between affected work packages and "doing" organizations.

Figure 29 illustrates time-phasing of engineering changes.

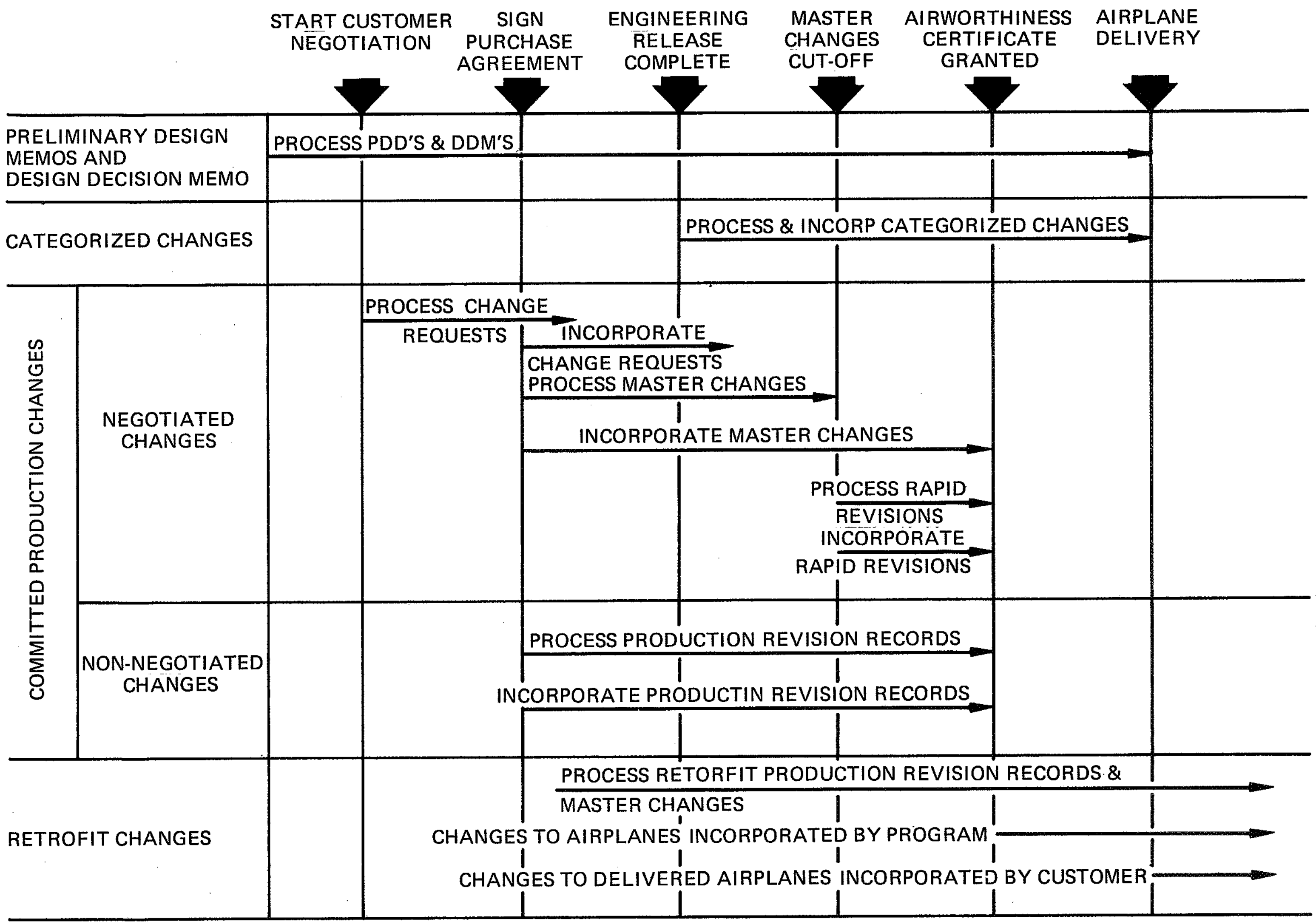


Figure 29.—Time Phasing of Engineering Changes (Typical Flow)

8.0 DATA MANAGEMENT

This section delineates the responsibility for processing, storage, and retrieval of data generated by the product program.

8.1 DATA PROCESSING POLICY

A corporate policy establishes responsibilities for data processing in:

Business systems used to control or monitor resources applied to a program or to functions within the program, e.g., as cost and schedule management, configuration definition and changes thereto, change control processes, work allocations, and assignments.

Engineering business systems used in direct support of the design, planning, ordering, producing, or purchasing and accounting for hardware components, e.g., automated parts listing release system, and automated wire identification and accountability system, etc.

Engineering scientific systems used to construct geometry mathematical models, perform design and analysis, construct detail part definitions, etc.

Manufacturing systems used for material and part inventory, numerical control machining, etc.

A top-down approach should be used to design each system. At the top level, the system is described in gross terms to identify input and output requirements, interfunctional relationships, and interfaces with other organizations. Each succeeding lower level describes the processes or functions in greater detail. The lowest level contains the individual elements that are applied to meet the requirements of higher levels. This approach ensures that all required processes are clearly identified and accounted for in a cost-effective manner.

Each system is documented completely to provide continuity of system development and implementation, an orderly transition of changes in personnel, and schedule or operational compliance. Documents are prepared for total system design, operating, and maintenance requirements; user requirements; and change control procedures. These documents establish controls and procedures and assign responsibilities for integrity of source data and reporting requirements. When the system is implemented, formal change control procedures are initiated to ensure that no system modification will adversely affect interfacing systems or other users of the data.

This policy should encourage formal interface between systems and make provisions for data administration.

8.2 DATA ADMINISTRATION

A data administrative function is recommended. The data bank administrator(s) is responsible for computer-stored information and will design, organize, and implement a data storage and retrieval system. Since scientific data processing is technical-discipline-oriented, it will be necessary for the data administrator(s) to have at least one technical data administrator from each engineering group. This person will be responsible for the design of the relationships which will be used to store and retrieve information unique to that engineering discipline.

9.0 ENGINEERING PERFORMANCE REPORTING

Effective planning and control requires a disciplined system to provide periodic comparisons of actual and predicted engineering performance. Cost and schedule problems requiring management attention and action on a timely basis must be identified and reviewed on a continuous basis. To effectively meet objectives, the reporting system must contain or be interfaced with key data.

9.1 ENGINEERING SCHEDULE TRACKING SYSTEM

The purpose of the tracking systems is to:

Provide a centralized source for schedule and status control, on a regular cycle, utilizing automatic data processing equipment

Provide engineering organizations with reports that reflect a 30-day visibility of their scheduled milestones

All committed engineering milestones should be input into the data storage and retrieval system with adequate video displays. Supplemental weekly reports to the responsible and receiving organizations should be made by status source document (SSD). The SSD (fig. 30) is a report showing selected data from the data storage and retrieval system, by organization, for all milestones due within the next 30 days. It is also the vehicle by which late item reports and associated statistical summaries are developed for program visibility and problem solutions.

Each Monday, the work package manager or group supervisor should receive an SSD report reflecting a 30 day look-ahead at his scheduled milestones. He should review each listed milestone and supply status information as follows:

a) If the milestone has been or will be accomplished in all respects before midnight on Thursday (see "Status to be reported as of..." date in the upper right hand corner of the SSD page), enter the completion date in the status column followed by an "A" (for accomplished).

b) If the SSD milestone is scheduled to occur beyond the Thursday "Status to be reported as of..." date, and if it is anticipated that it will be accomplished on schedule, enter the anticipated accomplishment date in the status column followed by an "E" (for estimated) status code.

PROGRAM STATUS SOURCE DOCUMENT STATUS AS OF 1-30-75

))

PIN 14-37-6290 SEALS

	RESP ORG	SCHEDULE	STATUS	RECEIVING ORG	
RELEASE ASSY DWG	2-6257-21	02-07-75	02-07-75 E	BSC	F
				SSDCD	A
				C+E	D
				PPTLV	A

******REMARKS******

THE ACCOMPLISHMENT OF THIS MILESTONE
MUST BE VERIFIED

******HISTORY*****

AS OF	.....SCHEDULE........	........STATUS	
04-25	INIT. DATE 02-07-75	ON-SCHED	0

))

PIN 14-61-1900 FRAMES C
39.85 – 220.56

	RESP ORG	SCHEDULE	STATUS	RECEIVING ORG	
RELEASE INSTL DWG	2-6257-21	01-10-75	01-31-75 E	BSC	E
				SSDCD	A
				C+E	D
				RPTLV	A

******REMARKS******

THE ACCOMPLISHMENT OF THIS MILESTONE
MUST BE VERIFIED

******HISTORY*****

AS OF	.....SCHEDULE......	......STATUS	
05-02	INIT DATE 01-10-75	ON-SCHED	0

))

PIN 14-61-2090 BULKHEAD ASSEMBLIES–
INT FIN SUPPORT

	RESP ORG	SCHEDULE	STATUS	RECEIVING ORG	
RELEASE INSTL DWG	2-6257-21	02-17-75	02-17-75 S	BSC	E
				SSDCD	A
				C+E	D
				RPTLV	A

******REMARKS******

REASON–
1. MORE COMPLEX THAN ORIG EST
2. LATE LOADS DUE TO DECISION
   TO REDUCE WT

ACTION–
WILL RELEASE AFT AUX 1-16-75, MID
1-23-75 + FWD AUX 1-31-75.

CONSEQUENCE–
MAY AFFECT BODY DOCK LOAD.

THE ACCOMPLISHMENT OF THIS MILESTONE
MUST BE VERIFIED

******HISTORY*****

AS OF	.....SCHEDULE......	......STATUS	
05-02	INIT DATE 02-17-75	SLIPPAGE	0

Figure 30.—Engineering Schedule Status

c) If it is anticipated that the SSD milestone will not be accomplished completely on schedule, enter the new estimated completion date or NA (for "not available") in the status column (followed by an "E" (for "estimated") status code. Remarks by the supervisor responsible for the milestone, which explain why the release will not be accomplished as scheduled, must specifically include information in the following three categories:

REASON: The reason(s) the schedule was not met

ACTION: The action(s) taken or to be taken, e.g., overtime, additional manpower, or coordinating a revised schedule with manufacturing/materiel

CONSEQUENCE: A comprehensive statement assessing the impact of a late release on the receiving organization and delivery of the end item. The reporting supervisor will coordinate with manufacturing, materiel, and other external/internal affected organizations, as required, to develop the consequence statement. Names of responsible supervisors from affected organizations will be included in the statement to support upper management review.

d) If the SSD milestone has been cancelled, enter the date of cancellation in the status column followed by an "X" (for cancelled) in the space provided for status code, with pertinent remarks

e) If further effort toward the accomplishment of the SSD milestone has been suspended pending official redirection, enter the date that the effort was stopped in the status column followed by a "Y" (for suspended) in the space provided for status code. Add appropriate remarks, including reference to the official correspondence justifying the cessation of effort.

f) If the SSD milestone is not the responsibility of the organization listed in the responsible organization field, note the correct responsible organization, if known.

Late item reports will be generated from the SSD outputs for schedule problem identification and resolution. These reports will include:

Reporting date

Work package identifier

Program item number

Package title

Responsible organization and supervisor

Milestone item description

Schedule source

Scheduled release date

Estimated completion date

Remarks:

Reason (for late release)

Consequence (effect of late release on program)

Action (required to minimize program impact)

The SSD is also the source for the generation of the total engineering release status (see fig. 31).

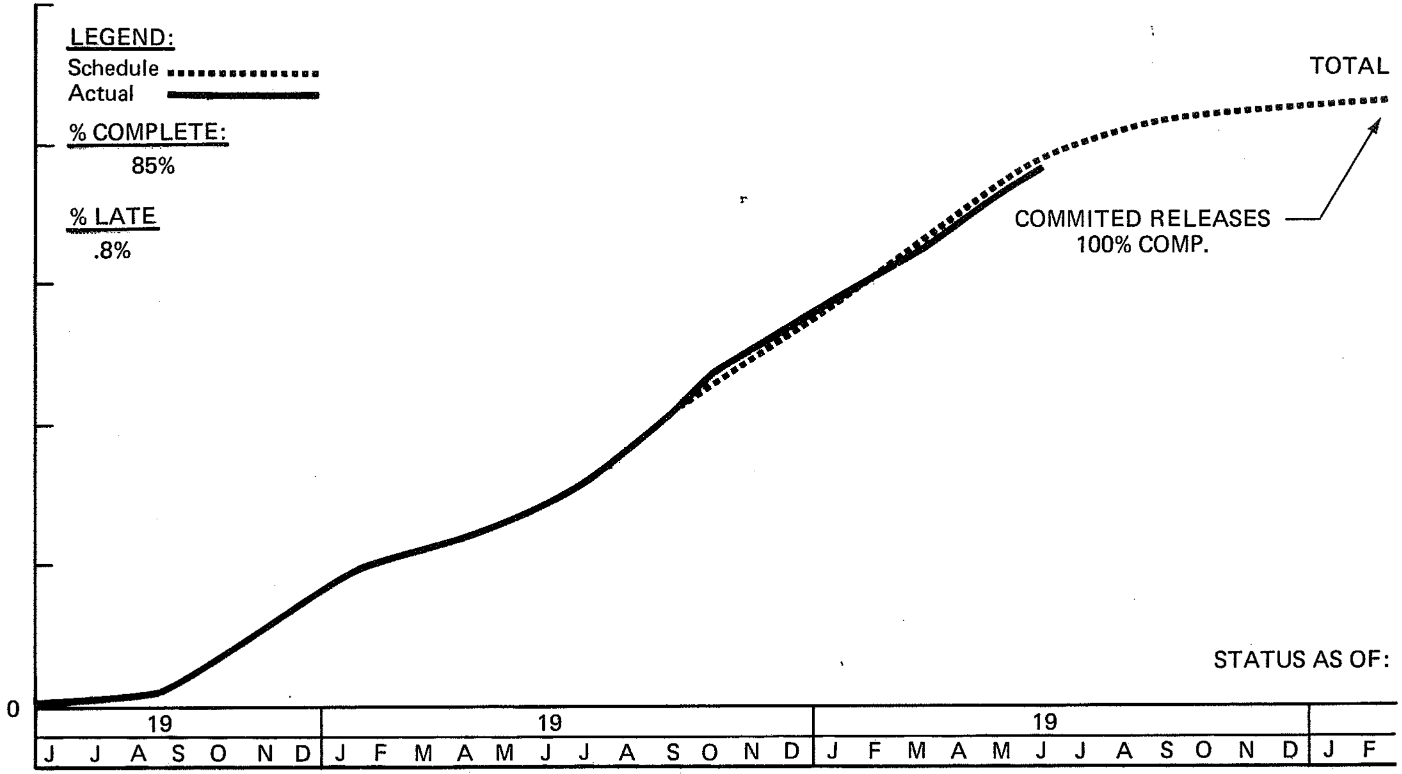
9.2 ENGINEERING BUDGET TRACKING SYSTEM: JOB STATUS REPORT

All elements of the engineering cost tracking system should be directly related to the WBS (see sec. 4.1). Reports to the functional organization should be to WBS levels 4 and 5. Reports to program manangement should be summarized to levels 2 and 3.

Supplemental weekly working reports are submitted via the job status (JS) report form (fig. 32.), which is a performance-reporting element providing a control tool to cost accounting and higher-level managers for all direct and overhead work. The report is a weekly computer printout of engineering and developmental labor budgets, balance-to-complete schedules, and expenditures for each cost account by accounting month and summarized at task, change, and organizational levels.

9.2.1 GENERAL INFORMATION

Approved resource expenditure authorizations are the sources for initial budget input data.



	J	J	A	S	O	N	D	J	F
COMMITTED	35	53	70	196	339	581	720	958	1
ACTUALS	32	53	70	186	330	570	720	958	10
BEHIND	3	0	0	10	9	11	0	0	2

Figure 31.—Total Engineering Project Design Release Status

```
   B94-J20-027  ENGINEERING                                          4 OF 5(26)                                                                    03-22-7
(1)JOB STATUS BY ORGN -ALL PROGRAMS-   JAN     FEB     MAR     APR     MAY     JUN     JUL     AUG(4)   SEP     OCT     NOV     DEC
   --------------------------      (3)EWA 20407  CNP ---7-                                   OPLOO 5 78407   8109   00107(5)SRC OGZ(6)JOB 0563625
   EXPENDED FOR WK NUMBER 841         SOFTWARE STATUS AUTHENTICATION SYS-PH II THRU PRELIN DESIGN-LOE-0896A              (13) START 01-04-3
(1)HRS    176.0 EQ MWKS     4.6    (2)PE(20)          PS(21)          PB(22)                                              (14)COMPL 05-24-3
   -------------------------- EXP 73 (23) 3.9    5.9    4.7                                                                (15) COMTD 05-24-3
(8)ADJ            HRS    MMOS  SCH 73 (24)4.3    1.9    4.4     5.0     5.0                                                 (16)(EAC   58.(17)
(9)CUM EXP      2351.0   15.1  BUD 73 (25) 3.9    7.2    4.4     5.0     5.0                                                (18) (CAL   57.1
(10)FCST REM    1676.3   10.8                                                                                               (19)EXC-
(11)EAC         4027.3   25.9
   --------------------------
(12)BUDGET      3966     25.5
   --------------------------         EWA 20411  CNP --11-                                    OPLOO 5 78407   8109   00111   SRC OGZ   JOB 0563099
   EXPENDED FOR WK NUMBER 841         IPO MODEM CHANGE-ECP PREP & SYSTEM DEFINITION-LOE-0896A                                       START 01-04-3
   HRS          EQ MWKS               PE                PS                PB                                                          COMPL 02-22-3
   -------------------------- EXP 73     1.5     3.0                                                                                 COMTD 02-22-3
   ADJ            HRS    MMOS  SCH 73     4.5     1.9                                                                                 (EAC  100.0 M
   CUM EXP       840.0    5.4  BUD 73     3.8     1.9                                                                                 (CAL  150.0
   FCST REM                                                                                                                           EXC- PAST DUE
   EAC           840.0    5.4
   --------------------------
   BUDGET        805      5.7

   ***TOTALS FOR  ENGINEERING  (29)2-6763-0
(27)TOTAL                             PE                PS                PB        27.0
   EXPENDED FOR WK NUMBER 841 EXP 73     7.6     8.9     4.7                                                                         PERCENT(28)60.0
   HRS   176.0 EQ MWKS      4.6 SCH 73     9.7     3.8     4.4     5.0     5.0
   -------------------------- BUD 73     8.6     9.1     4.4     5.0     5.0
   ADJ.           HRS    MMOS
   CUM EXP      6912.7   44.4
   FCST REM     1676.3   10.8
   FAC          8589.0   55.2
   --------------------------
   BUDGET       8905     59.1
```

Figure 32.—Job Status Report

Primes shall adhere to assigned budgets and shall establish and maintain realistic manpower allocations for all committed authorized work. Unauthorized anticipated work may be included in the Job Status Report, if desired, to reflect potential manpower requirements. However, no expenditures may be made against the items until authorized. Explanation and illustration of Job Status Report entries is given in figure 32.

9.2.2 REPORTING RESPONSIBILITIES

9.2.2.1 Task and Cost Account Managers

Job status data is reviewed weekly to confirm validity of manning plans and completion dates and revise the JS correction copy with red pencil as required. Revisions/corrections are submitted to engineering costs and schedules.

Unauthorized committed or anticipated work is entered on the JS report as desired for manpower planning or as requested by higher management.

9.2.2.2 Engineering Costs and Schedules

Assistance is provided to the primes with the initiation of and revisions to JS data to ensure that the input is complete and accurate.

The job status report is distributed to appropriate supervisors.

The job status report is analyzed for potential problem areas and corrective action (e.g., budget revision, manning changes, completion date revisions, etc.) is recommended.

9.2.3 JOB STATUS REPORT FORMAT

The following items describe entries on the job status report (see fig. 32.)

1. JOB STATUS--the name of the report
2. Column to identify the horizontal entries as manpower expended (EXP), scheduled (SCH), or budgeted (BUD)
3. WORK ITEM IDENTIFICATION--includes identifying numbers for work authorized

4. CHARGE NUMBER--includes the work type code, account number, package identifier, and item or serial number assigned for the specific job

5. SRC--special requirements code: a three-character entry of one alpha and two alphanumeric combinations identifying the business code (e.g., authorized by basic contract, authorized by firm change order (CO) for which hours have been negotiated, authorized by firm CO but not negotiated, committed but unauthorized, etc.) and the applicable contract. This code is used primarily for machine-sorting for summarization of program data.

6. JOB--job number: the machine address used to store budget, expenditure, and schedule information and to collect labor hours and dollars charged to this item on employee time record.

7. EXPENDED FOR WEEK NUMBER--manhours and equivalent men expended on this job during the week covered by the report. The three-position numerical code is used for machine processing purposes to identify the week covered by the report.

8. ADJ--those hours adjusted into or out of cumulative expenditures during the week to correct charging errors or other erroneous information contained in previous reports

9. CUM EXP--cumulative expenditures: the total manhours and equivalent manmonths expended through the current report date

10. FCST REM--forecast remaining: the total scheduled manhours and equivalent manmonths remaining until completion of the job

11. EAC--estimate at completion: total planned effort at completion in manhours and equivalent manmonths. It constitutes expenditures to date plus forecast of remaining effort.

12. BUDGET--budget in terms of manhours and equivalent manmonths as authorized by implementing form. Budget cannot be changed without approved revision of implementing form.

13. START--date on which job was scheduled to begin

14. COMPL--completion date now planned per latest schedule

15. COMTD--original completion date committed

16. EAC--percent of EAC hours that have been expended through current report date

17. M--manual schedule indicating that scheduled manmonths represent a direct month-by-month input

18. CAL--percent of calendar time between start date and completion date that has elapsed through current report date

19. EXC--exception signal. The following exception signals may appear in this space, each indicating a situation which should be given attention:

    OVERRUN--total planned exceeds budget by 200 hours or 25 percent (whichever is smaller)

    UNDERRUN--total planned is less than budget by 200 hours or 25 percent (whichever is smaller)

    NO START--past start date with no expenditure to date

    PAST DUE--job still open beyond completion date

    SCHEDULE--no schedule has been provided for the item

    INACTIVE--job number has been closed

20. PE--past manpower expenditures (cum manmonths): not reflected on the expenditures lines

21. PS--past manning schedule (cum manmonths): not reflected on the schedules lines

22. PB--past budget (cum manmonths): not reflected on the budget lines

23. Current year expenditures in equivalent manmonths

24. Current and future years' manning schedule in equivalent manmonths

25. Current and future years' budget in equivalent manmonths

26. 4 of 5--indicates the accounting week of the month being reported, the fourth week of a four-week month. Since March, June, September, and December each contain five accounting weeks, reports during these months shall carry "x of 5" in this space.

27. TOTAL--total expended, total budgeted, and total scheduled equivalent manmonths for all jobs previously listed. This entry appears near the bottom of the last page for the group.

28. PERCENT--the percent of the organization's EAC manhours that have been expended to date

29. ORGN--the group level number of the organization covered by the report

10.0 PROGRAM VISIBILITY

Normal display of management information will be accomplished by automated preformatted displays of data. This will provide management with the capability to review plans, schedules, and costs. The plans will outline the sequence of design and analysis required at each step. As the design progresses, the plans will be updated to show the completion of each step. This will provide management with well-supported capability to track the costs, such as design engineering and development cost, and estimates of the production cost, product support cost, and product operation cost. Manual displays will also be used. As time permits, all data for the reports described in previous sections and the permanent displays shown in section 10.1 should be interfaced with data storage and retrieval systems, and a display format should be developed accordingly.

10.1 VISIBILITY ROOM

The program visibility room is the focal point of program control, information, and activity. The information displayed in the room must be designed to assist in accomplishing the management task. This entails:

Selection of the proper indices and parameters to measure and display

Clear presentation of the information

Satisfactory physical equipment to view the data

Timely maintenance

Regular use of the room

Some managers require different types of reports or depend on different parameters to indicate program status, therefore, the data displayed is tailored to the desires of the managers. It may be designed to utilize the concept of management by exception, by emphasizing "critical" or "problem" areas in the displays.

The primary use of a visibility room is a meeting place for program reviews, meetings with customers, and other large meetings as can be accommodated with the accessibility of the displays. Display boards are provided for individual departments to maintain functional data such that departmental meetings may also be held in the room as the schedule permits. However, the arrangement of the room is such as to emphasize "top-down" program control, with summary program information displayed most prominently and first-level backup data easily accessible.

Management information is accessed and displayed using the latest information from the data storage and retrieval system. As computer technology advances, the current practice of display boards, viewgraphs, etc., can be replaced with large-screen display devices that project preformatted displays from the data storage and retrieval system.

Careful arrangement of facilities is required to achieve the best utilization of the visibility room. There can be different arrangements of visibility rooms dependent on the program, budget, space, and management requirements. One example of a suitable room is shown in figure 33.

Two banks of 5' x 8' translucent, back-lighted plastic sliding boards are provided. Boards are removable so that they can be in work outside the visibility room while the room is in use. The adjacent work room contains displays in work, inactive displays, storage, and a camera to allow rapid availability of copies of any display at any time.

10.2 VISIBILITY DISPLAYS

Management information display data will be accessed through terminals using the latest information from the data storage and retrieval system in pre-established format. Types of data to be displayed are:

General:

- Three-view drawing
- Organization chart
- Management systems flow charts

Program status:

- WBS/cost control matrix
- Program schedules and status
- Program cost status
- Manpower forecasts and actuals
- Problem item summaries
- Action Items

Functional Status:

Typical formats for some of these displays are shown in figures 34 through 37.

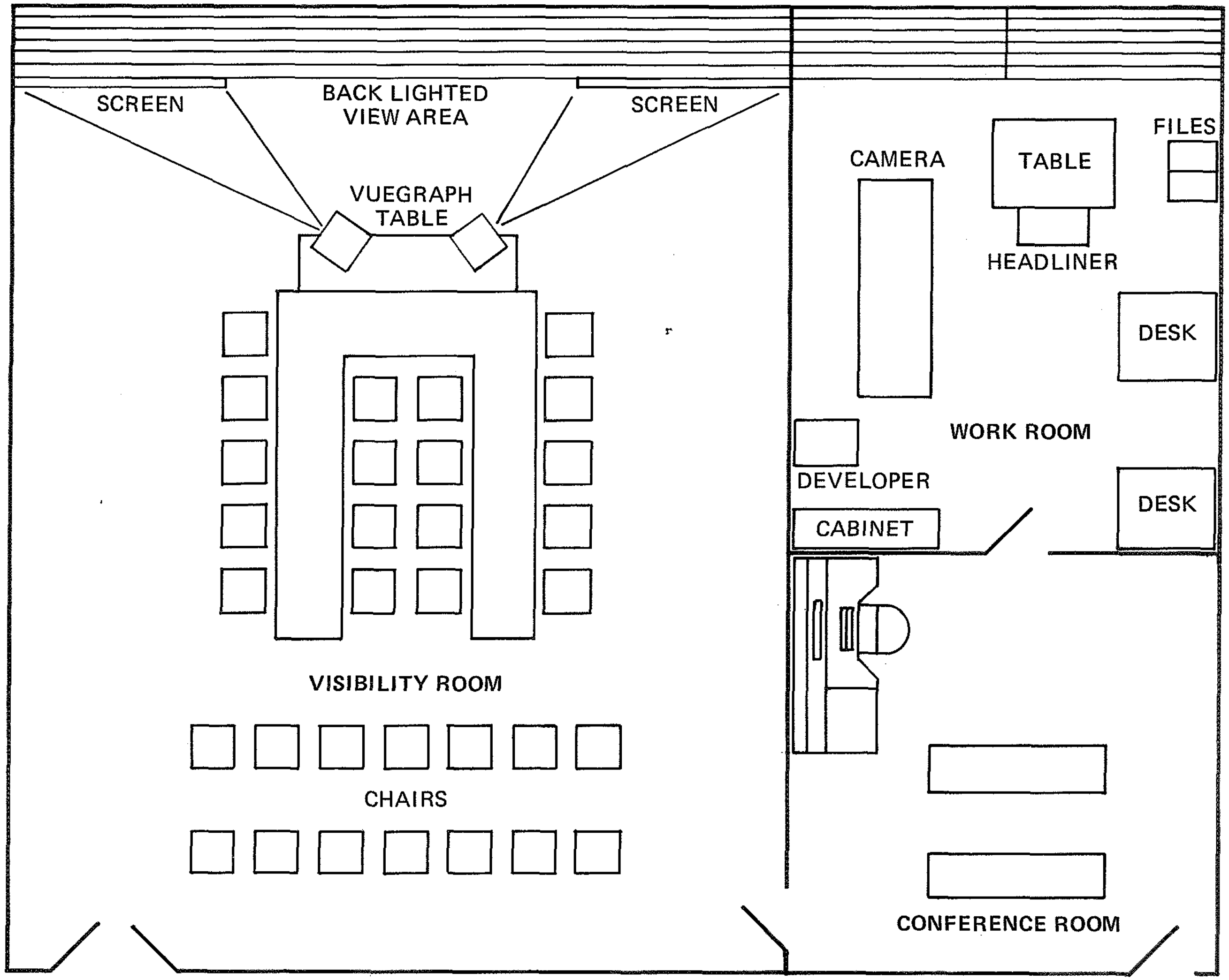


Figure 33.—Visibility Room Layout

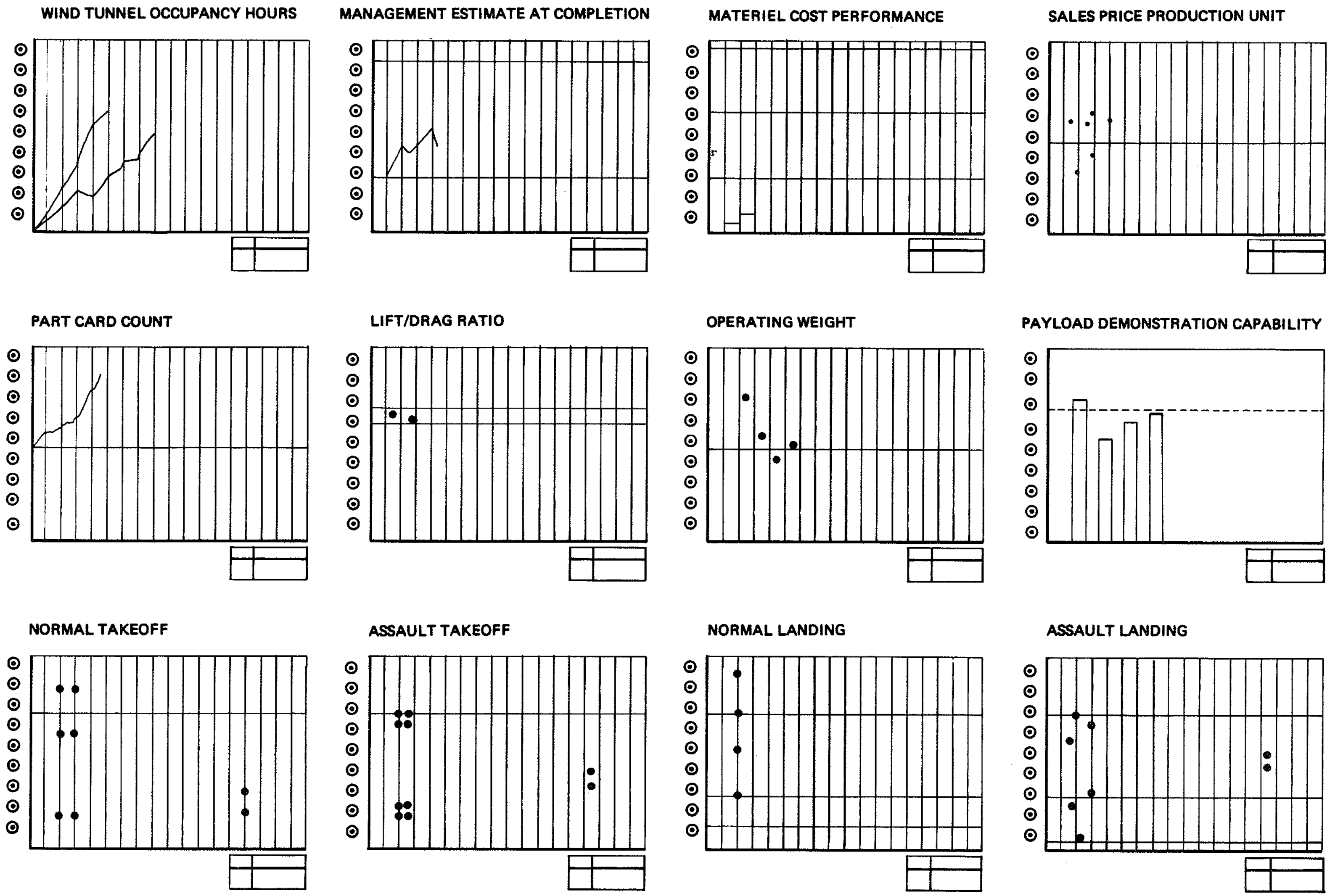


Figure 34.—Key Performance Tracking Parameters Preliminary Design Period

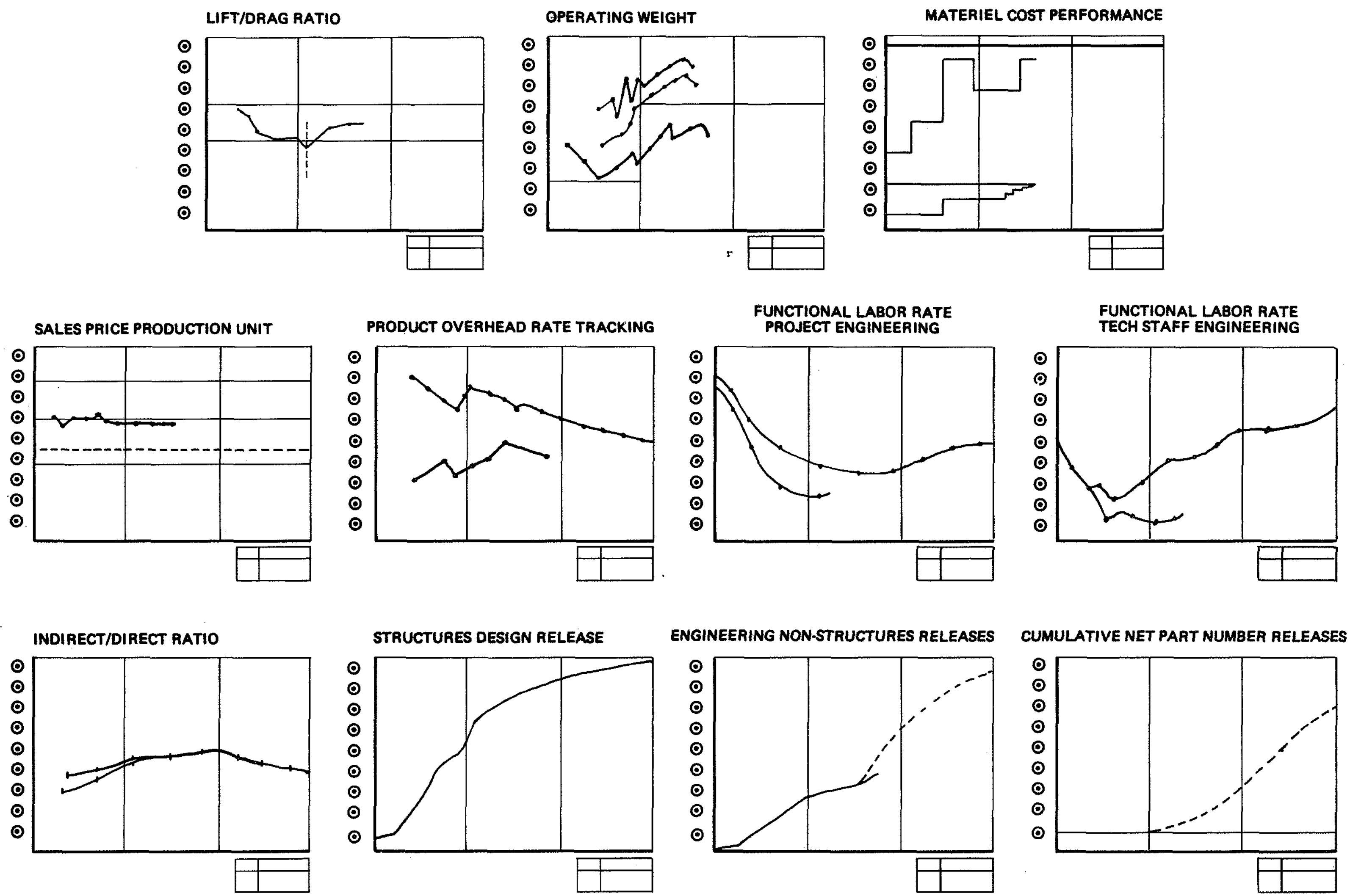


Figure 35.—Key Performance Tracking Parameters, Design Period

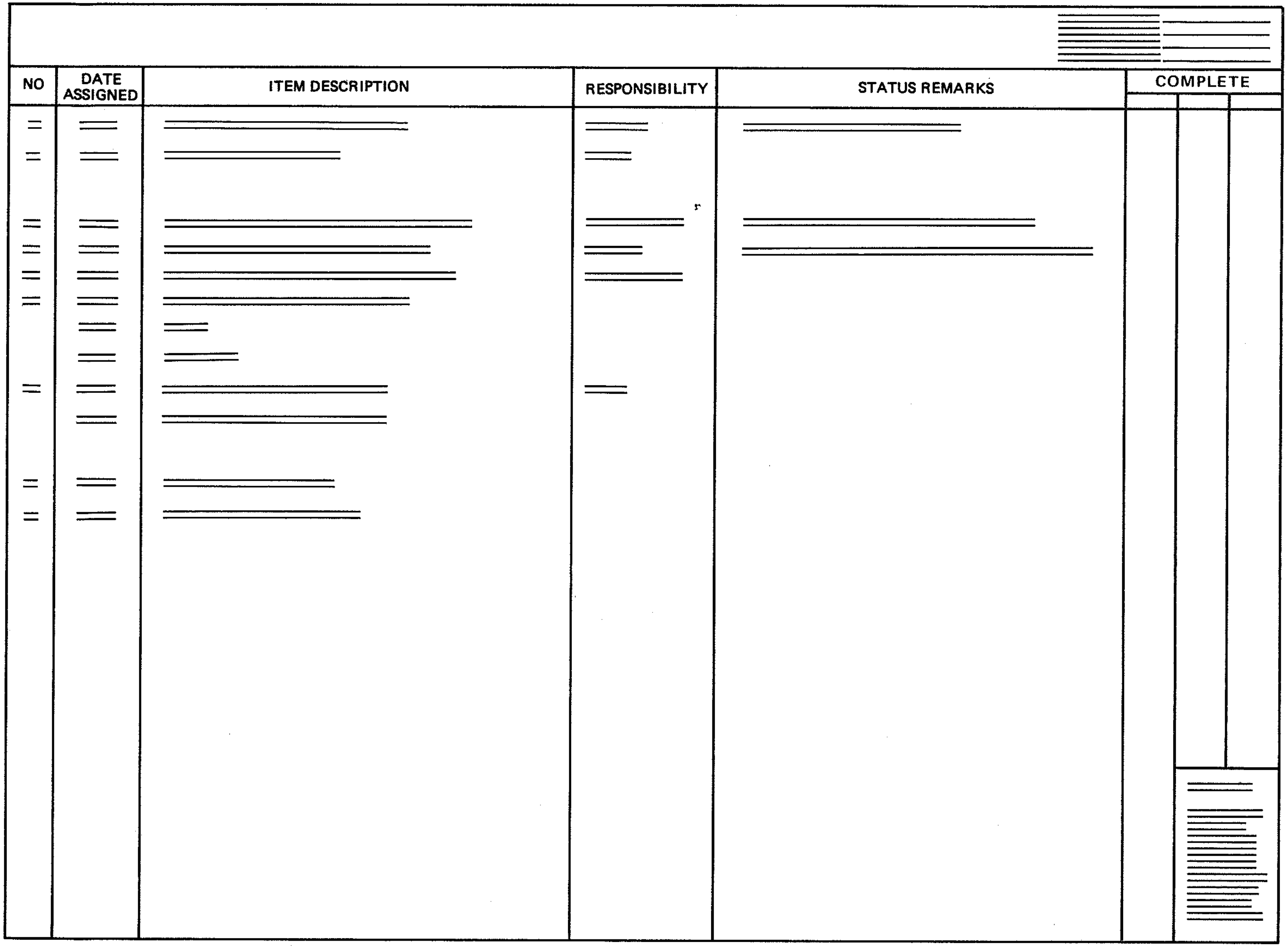


Figure 36.—Action Items

NO	DATE ASSIGNED	DESCRIPTION	RESPONSIBLE MANAGER	ESTIMATED CLOSURE DATE/REMARKS

Figure 37.—Top Program Problems

11.0 CONCLUSIONS

Systems used to manage a product program are not unique within the aerospace industry and are tailored by each company to suit its needs. It is concluded that the system described in this document should not be implemented into IPAD. However, cost and schedule data should be collected relative to use of the IPAD system and it should be possible for each company to interface or integrate its management systems with the IPAD system.

APPENDIX A

GLOSSARY

Configuration management

Continuous process of defining, identifying, and controlling baseline product configuration at all design phases (conceptual, preliminary, and detail) and at the program's production phase.

Design-to-cost

Formal design discipline involving the establishment of product cost goals prior to detail design commitment and the application of specific management principles to achieve such goals through all phases of the product life cycle.

Job status report

A weekly computer report of program performance data to cost accounting and management for all direct and overhead work.

Life-cycle costs

Accurate, predictable costs of the product during its life cycle from acquisition through replacement based on estimates updated throughout product design phases.

Program item number (PIN)

A number that relates an item of work to the work breakdown structure, used as a primary index to work items and for cost collection.

Schedule management

A hierarchical schedule system controlling a master baseline schedule and related detail schedules with provision to compensate for variances.

Work breakdown structure (WBS)

A structured index to all elements of work and all end items produced by a product program.

APPENDIX B
SI–U.S. CONVERSION TABLE

METRIC TABLES

LENGTH

Myriameter	10,000 meters	6.2137 miles.	Meter	1 meter	39.37 inches.
Kilometer	1,000 meters	0.62137 mile.	Decimeter	0.1 meter	3.937 inches.
Hectometer	100 meters	328 feet 1 inch.	Centimeter	0.01 meter	0.3937 inch.
Dekameter	10 meters	393.7 inches.	Millimeter	0.001 meter	0.0394 inch.

AREA

Hectare	10,000 square meters	2.471 acres.
Are	100 square meters	119.6 square yards.
Centiare	1 square meter	1,550 square inches.

WEIGHT

Name	Number of grams	Volume corresponding to weight	Avoirdupois weight
Metric ton, millier or tonneau	1,000,000	1 cubic meter	2.204.6 pounds.
Quintal	100,000	1 hectoliter	220.46 pounds.
Myriagram	10,000	1 dekaliter	22.046 pounds.
Kilogram or kilo	1,000	1 liter	2.2046 pounds.
Hectogram	100	1 deciliter	3.5274 ounces.
Dekagram	10	10 cubic centimeters	0.3527 ounces.
Gram	1	1 cubic centimeter	15.432 grains.
Decigram	.1	0.1 cubic centimeter	1.5432 grains.
Centigram	.01	10 cubic millimeters	0.1543 grain.
Milligram	.001	1 cubic millimeter	0.0154 grain.

CAPACITY

Name	Number of liters	Metric cubic measure	United States measure	British measure
Kiloliter or stere	1,000	1 cubic meter	1.308 cubic yards	1.308 cubic yards.
Hectoliter	100	0.1 cubic meter	2.838 bushels; 26.417 gallons.	2.75 bushels; 22.00 gallons.
Dekaliter	10	10 cubic decimeters	1.135 pecks; 2.6417 gallons.	8.80 quarts; 2.200 gallons.
Liter	1	1 cubic decimeter	0.908 dry quart; 1.0567 liquid quarts.	0.880 quart.
Deciliter	.1	0.1 cubic decimeter.	6.1023 cubic inches; 0.845 gill.	0.704 gill.
Centiliter	.01	10 cubic centimeters.	0.6102 cubic inch; 0.338 fluid ounce.	0.352 fluid ounce.
Milliliter	.001	1 cubic centimeter	0.061 cubic inch; 0.271 fluid dram.	0.284 fluid dram.

COMMON MEASURES AND THEIR METRIC EQUIVALENTS

Common measure	Equivalent	Common measure	Equivalent
Inch	2.54 centimeters.	Dry quart, United States	1.101 liters.
Foot	0.3048 meter.	Quart, imperial	1.136 liters.
Yard	0.9144 meter.	Gallon, United States	3.785 liters.
Rod	5.029 meters.	Gallon, imperial	4.546 liters.
Mile	1.6093 kilometers.	Peck, United States	8.810 liters.
Square inch	6.452 square centimeters.	Peck, imperial	9.092 liters.
Square foot	0.0929 square meter.	Bushel, United States	35.24 liters.
Square yard	0.836 square meter.	Bushel, imperial	36.37 liters.
Square rod	25.29 square meters.	Ounce, avoirdupois	28.35 grams.
Acre	0.4047 hectare.	Pound, avoirdupois	0.4536 kilogram.
Square mile	259 hectares.	Ton, long	1.0160 metric tons.
Cubic inch	16.39 cubic centimeters.	Ton, short	0.9072 metric ton.
Cubic foot	0.0283 cubic meter.	Grain	0.0648 gram.
Cubic yard	0.7646 cubic meter.	Ounce, troy	31.103 grams.
Cord	3.625 steres.	Pound, troy	0.3732 kilogram.
Liquid quart, United States	0.9463 liter.		

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15. Supplementary Notes

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Ralph E. Miller, Jr., Boeing IPAD Program Manager

Topical Report

16. Abstract

IPAD is a computing system to support company-wide design information processing. This document presents a brief description of the management system used to direct and control a product-oriented program. This document, together with the reference design process (CR 2981) and the manufacture interactions with the design process (CR 2982), comprises the reference information that forms the basis for specifying IPAD system requirements.

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